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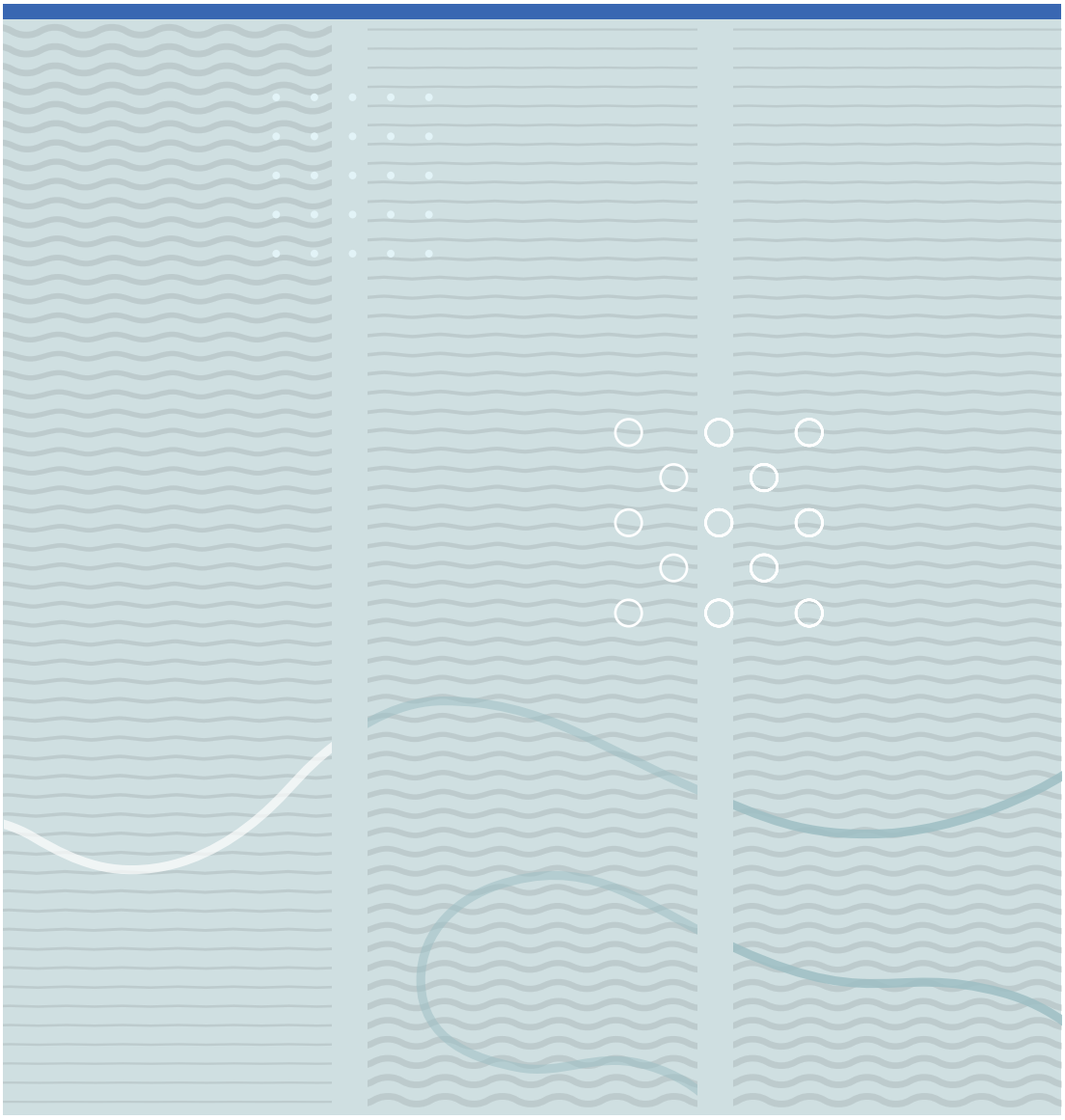
Elin Kjelle

# Mobile radiography services in nursing homes - utilisation, costs and organisation



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# Mobile radiography services in nursing homes - utilisation, costs and organisation

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**Person-Centred Healthcare**

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To Henrik, Daniel and Jan Håvard

"*At the same time as it became clear what an enormous task it was, treating those wounded from this war, the advantages of X-rays were increasingly understood, appreciated, and sought after every day. It was this situation the X-ray vehicles helped ease by providing a temporary solution*"

Marie Curie on "Petite Curies" during World War I

# Preface

Think of an elderly woman you know, maybe your grandmother, aunt, or mother. She is 90 years old, living with dementia, and has a heart condition. Because of this, she spends her days in a nursing home. The nursing home is a good place for her. One day, she slips on the floor in the corridor and falls. The doctor in the nursing home suspects a hip fracture but however cannot be sure, so an X-ray is needed.

To do the X-ray our patient needs to travel for 30 minutes to the local hospital. Since she is in a lot of pain, the nurse calls for an ambulance. In addition, the nurse calls you; she needs you to accompany the patient to the hospital.

You travel with your relative in the ambulance – she is already scared, confused and stressed out. At the imaging department, you stand by her stretcher in the waiting room. The radiographer welcomes you, and takes her in for the examination. She is extremely confused about this new place, and all the new people she meets. After the examination, you are both back in the waiting room; half an hour later an assistant tells you an ambulance has been booked to take her back to the nursing home. There was no fracture.

Hours pass by in the corridor. You ask the personnel at the imaging department about how long the wait will be, how to help your relative to the bathroom, and where to get food. The radiographers and assistants help as much as they can. However the patient is now totally confused, exhausted and has twice missed taking her medication. Finally after five hours in the corridor, the ambulance arrives to take her back. In the nursing home, she goes into delirium and the nurse assistants and nurse try to take care of her as best they can... In short, is this the best way to take care of a nursing home resident?

Through my experience as a radiographer, I have seen such situations play out many times. In this thesis, which contributes to the person-centred healthcare research programme at the University of South-eastern Norway, I explore a service rooted in the efforts of Marie Curie more than a 100 years ago. I thereby hope to contribute to preventing such situations for nursing home residents and their families in the future.

# Acknowledgements

This thesis would not have been a reality had it not been for the initiative from the project group of mobile radiography services at Vestre Viken Hospital Trust. Thank you for your commitment to services for nursing home residents, and your inspiration and support.

Furthermore, this thesis would not have been possible without the collaboration of all the managers, radiographers, and IT-radiographers who contributed to the data collection. I would like to express my sincere gratitude to you for taking time out of your busy schedule to meet with me for an interview, or to extract data from the radiology information systems.

As a PhD candidate enrolled in the PhD programme 'Person-Centred Healthcare', I have carried out this thesis at the Faculty of Health and Social Sciences at the University of South-Eastern Norway from Aug 1 2015 to date. I would like to thank the Department of Optometry, Radiography and Lighting Design for facilitating my work on this thesis.

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# Abstract

**Background:** Due to demographic changes in the western world, with an ageing population and fewer resources for health services, there is a need for a new way of organising and delivering health services to the population. An increase in the number of nursing home residents worldwide is expected as people live longer and have multiple comorbidities. In addition, the number of persons living with dementia is increasing rapidly. There is a drive internationally towards more integrated, people-centred health services focusing on the needs of the population and individuals, rather than a cure-based hospital or disease-centred health service. In diagnostic imaging, mobile radiography services could be a way of delivering imaging services to nursing home residents focused on their needs for a familiar environment and coordinated care. Mobile radiography service is a telemedicine application, where the health service is delivered at different localisations connected by information and communication technology. The use of more telemedicine applications is highlighted as one of the measures necessary to meet future challenges in the health services. However, telemedicine applications are often blocked for wider implementation in the current health services because of organisational, financial and legislative barriers, or reluctance to use new technology. To increase the quality of telemedicine studies and produce knowledge useful to decision-makers, a model for the assessment of telemedicine services (MAST) has been developed. This is used in my thesis to assess conditions for and current knowledge on mobile radiography services, and to explore mobile radiography services in nursing homes in three of MAST's domains. Furthermore, mobile radiography services in nursing homes will be analysed in a people-centred health service perspective.

**Aim:** The main aim of this thesis is to explore utilisation of mobile radiography services in nursing homes and the economic and organisational aspects of these services, thus contributing to the delivery of integrated, people-centred health services to nursing home residents. This aim was achieved through four studies.

**Materials and methods:** MAST was used as a model for structuring the assessment of mobile radiography services.

*Paper I:* A systematic review of the outcomes of mobile radiography services for nursing home residents and society. Searches were made in Medline, Cochrane, PubMed, Embase, and Swemed+. Through predefined inclusion criteria, all titles and abstracts were screened. In addition, a full text assessment was made including a quality appraisal using MMAT or CASP appraisal tools. Data were extracted using a summary table. Results were narratively summarised.

*Paper II*: Exploring utilisation of diagnostic imaging among nursing home residents and the effects of mobile radiography services. Data on referred examinations from nursing homes in 2015 were collected from radiology information systems at eleven hospitals from all health regions of Norway. Hospitals were divided into two categories: with and without mobile radiography services. The Chi-squared test was used to compare these categories.

*Paper III*: A cost-analysis using a decision tree model in TreeAge Pro. The model compared two alternatives: mobile radiography services combined with hospital-based services and hospital-based services alone. The model included both the examination and treatment of the nursing home residents. Input probabilities and costs were derived from previous research, reports and hospital data. Monte Carlo simulations of 1000 residents were run through the model in a probabilistic sensitivity analysis (PSA) and paired-samples t-tests was used to compare the alternatives.

*Paper IV*: Semi-structured interviews with eleven managers from both hospitals and municipalities were conducted in order to explore barriers and facilitators for implementing mobile radiography services in Norway. The interview guide focused on barriers and facilitators in different phases of implementation. Thematic analysis through the framework method was used for inductive-deductive analysis of data by a research team.

Results: *Paper I*: The review included ten publications. Overarching, resident, and societal outcomes were identified. The overarching outcomes were interlinked with the outcomes for residents and society. The reduction in hospitalisations and outpatient visits and transfers, and at the same time an increase in radiographic examinations were considered overarching outcomes. These lead to better treatment and care for nursing home residents as well as increased psychosocial well-being. These outcomes also gave a more efficient use of resources and thus lower costs per examination on a societal level.

*Paper II*: The analysis showed an underuse of diagnostic imaging among nursing home residents compared to the general population (0.9 examinations per person per year), with 0.5 (with mobile radiography) and 0.36 (without mobile radiography) examinations per nursing home bed per year. Mobile radiography services increased the proportion of plain radiography significantly. However, the proportion of CT and ultrasound reduced significantly when a mobile services was present. Of 11,066 examinations, 87% were plain radiography examinations, 8% were CT scans and 4% were ultrasound. The use of MRI, nuclear medicine, and other modalities was less than 1% each.

*Paper III*: The analysis showed a 30% cost reduction from a mean cost of €2,790 per resident examined and treated with hospital-based services to a mean cost of €1,946 with a combined service alternative. The difference in costs was significant ($p < 0.001$). The PSA showed cost reduction in all runs and the reduction would most likely be €560 to €1,080 per resident examined and treated in southeast Norway.

*Paper IV*: Barriers and facilitators for mobile radiography services were found on both micro, meso, and macro levels of the health services. The managers interviewed mainly experienced that the implementation was impeded by financial (reimbursement system), structural (lack of cross-level management), and procedural (lack of compatible communication systems) barriers. The main facilitators were external funding, and support and engagement from individuals in the cooperating organisations.

Conclusions: This thesis showed that:

Mobile radiography services contribute to increased access to imaging services. This could provide more accurate diagnosis and thus better treatment and care for most nursing home residents, tailored to their need for a familiar environment and coordinated services.

Mobile radiography services contribute to the strengthening of primary care. An increase in treatment given in the nursing home transfers tasks from hospitals to primary care, in line with the strategies for integrated, people-centred health services.

Mobile radiography services contribute to a better utilisation of healthcare resources, and reduce the cost per examination and treatment by 30%.

Barriers exist within the health services to large-scale implementation of mobile radiography services. These barriers are present in the management and funding of health services, and in the information technology systems.

Recommendation: This thesis showed a need for changes in the funding of health services in Norway in order to facilitate coordination and integration of health services and telemedicine applications. In addition, there is a need for stronger cooperative management across health service levels. Furthermore, there is a need for integrated information systems across organisations and a system for safe, wireless image transfer from mobile modalities.

Further research: This thesis suggests that more research is needed in the mobilisation of diagnostic imaging and spreading mobile radiography to other populations in need of diagnostic imaging outside hospitals and imaging centres.

Keywords: Mobile radiography services, diagnostic imaging, nursing home, nursing home residents, telemedicine, people-centred health services, integrated health services, mobile health units, MAST.

# List of papers

## Paper I

Kjelle, E. & Lysdahl, K.B. (2017). Mobile radiography services in nursing homes: A systematic review of residents' and societal outcomes. *BMC Health Services Research*, 17(1), 231. doi: https://doi.org/10.1186/s12913-017-2173-8

## Paper II

Kjelle, E., Lysdahl, K.B. & Olerud, H.M. Impact of mobile radiography services in nursing homes on the utilization of diagnostic imaging procedures. Submitted to BMC Health Services Research.

## Paper III

Kjelle, E., Kleven, L., Olerud, H.M. & Melberg, H.O. (2018). Cost-analysis of mobile radiography services for nursing home residents in Southeast Norway. *Journal of Evaluation in Clinical Practice,* 1-7. doi: 10.1111/jep.13058

## Paper IV

Kjelle, E., Lysdahl, K.B., Olerud, H.M., & Myklebust, A.M. (2018). Managers' experience of success criteria and barriers to implementing mobile radiography services in nursing homes in Norway: A qualitative study. *BMC Health Services Research*, 18(1), 301. doi: https://doi.org/10.1186/s12913-018-3115-9

# Abbreviations

CT – Computed tomography

DRG – Diagnosis Related Group

EC – European Commission

EUnetHTA - European Network for Health Technology Assessment

GP - General Practitioner

MAST - Model for Assessment of Telemedicine Applications

MMAT - Mixed Methods Appraisal Tool

MRI – Magnetic resonance imaging

NCRP - The Norwegian Classification of Radiological Procedures

NSD - The Norwegian Centre for Research Data.

PICO - A tool for creating precis literature searches including all or some of the following elements: Patient/problem, Intervention, Comparison, Outcome.

PSA - Probabilistic sensitivity analysis

QALY - Quality Adjusted Life Years

REC - Regional Committees for Medical and Health Research Ethics

RIS – Radiology information system

WHO - World Health Organisation

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# 1 Introduction

All over the world, especially in western societies, the population is ageing. People live longer with chronic illnesses, high morbidity and several co-morbidities while at the same time the birth rate is low [1]. With an ageing population with a higher morbidity than before, an increase in the number of people living in nursing homes or other care facilities for the elderly is expected [2, 3]. In Norway, the context of this thesis, health is improving, people live longer and expect protection from health risks [4-6]. The most common reasons for premature death are cancer and cardiovascular conditions. Moreover, one in two will experience psychiatric disorders throughout life. There are an estimated 70,000 people living with dementia in Norway today, and it is expected that there will be twice as many by 2050 [6]. These demographic changes the world over increase the financial pressure on the health services and these need to be adjusted in order to provide high-quality treatment and care to more people and at the same time retain a sustainable system [1, 4, 7-9].

Today there are barriers preventing older or chronically ill persons from accessing health services [1, 4]. These barriers are mainly caused by the organisation of health services and the economic incentives used. Even if the services are available, they are usually not designed for older or chronically ill persons [1, 4]. To meet this challenge, a drive towards a more person-centred health service in contrast to a doctor- or disease-centred service is occurring globally [10, 11]. The World Health Organisation (WHO) calls for reforms of health services all over the world in order to put in place a more integrated, people-centred health service. WHO's call focuses on the health of people in their communities and peoples role in shaping health policy and services based on a person-centred approach to health services [9, 11]. To achieve this, an evidence-based, dynamic health service with efficient use of new technology close to people's homes is needed [4, 8, 12]. The use of new technology and telemedicine has the potential to help solve some of the future challenges for the health services. Technology is central in order to integrate and individualise services, and increase access to services for older persons and those with chronic illnesses [4, 5, 7, 9, 13].

The research question examined in this thesis is related to diagnostic imaging. In the delivery of diagnostic imaging services, one of the options for meeting future challenges in healthcare is to mobilise modalities such as telemedicine services in order to be able to offer examinations in sites other than hospitals or imaging centres. Mobile radiography services have been introduced in a few countries since the early 2000's [14-20]. Earlier research has reported that mobile radiography services can provide radiographic examinations with adequate image quality in nursing homes or at people's homes [14-18, 21-24].

This thesis falls within the area of health services research. Health services research provides knowledge about the effectiveness and efficiency of health services and their impact on the health and well-being of individuals and the population in general [25]. In addition, this thesis is within the area of person-centred healthcare research on a societal or system level [11]. In person-centred research, research should be made for or with patients or participants rather than on them [11]. Furthermore, in person-centred research, critical reflexivity is important in order to understand the research process and the context in which the research is conducted, and how this affects the outcomes of research [11]. In addition, I assess mobile radiography services using a model for assessment of telemedicine services in order to provide useful knowledge to decision-makers in healthcare.

# 2 Background, definitions and aim

## 2.1 Health services

Health services include both personal and population-based health services [9]. These services are responsible for providing health services for persons, families, communities and the general population. Health services deliver the whole spectrum of care, including the promotion and prevention of disease, rehabilitation and palliative care as well as all levels of care in local communities and at hospitals [4, 5, 9, 26]. There are several definitions of 'health services', but in this thesis, WHO's definition of health services or health service delivery systems is used. Health services are:

*'All services dealing with the promotion, maintenance and restoration of health'* [9 p. 1].

Each country has its own way of organising and funding health services. The following section presents the Norwegian health services, as this is the context of the empirical research in this thesis.

### 2.1.1 The Norwegian health services and funding of health services in Norway

In Norway, the health services are mainly public and are divided into primary and specialist health services. The Norwegian welfare system has a strong principle of equal access to public services regardless of income or place of residence, and is funded through a National Insurance Scheme [27]. Norway is one of the most sparsley populated countries in Europe with about 15 people per km2. However, about 82% of the population live in urban areas. Norway has mostly barren terrain with mountains, vallys, small scattered plains, arctic tundra, and a long coast line indented with fjords [27]. This geography challenges the principle of equality in access to health services, and parts of the population live far away from hospital or a health centre [5, 27]. The health service is managed politically at ministry and municipality levels. The Ministry of Health and Care

Services manages specialised health services such as hospitals through regional health authorities [27], divided into four health regions: South-Eastern Norway, Western Norway, Mid-Norway, and Northern Norway [28]. Primary health services provided mainly by the municipalities include general practitioners (GPs), preventive care, nursing homes and rehabilitation [27]. In addition, a small part of the health service consists of private profit-making healthcare providers. Private hospitals provide <2% of hospitals beds, and private actors provide about 10% of the nursing home beds in Norway [27]. In diagnostic imaging, 23% of all radiological examinations in 2008 were conducted in the private sector [29].

The funding of health services in Norway is a combination of block grants (a global payment), activity-based funding , and patient fees [27]. In order to calculate the activity-based funding, classification systems have been developed for treatments in hospital and imaging procedures, for example [30, 31]. In imaging, the Norwegian Classification of Radiological Procedures (NCRP) is used. The NCRP codes has been developed in order to account for the number of examinations made on different modalities, and to calculate the reimbursement hospitals and imaging centres should receive [31]. This system provides detailed information on: anatomical region, organ or organ system examined, type of modality, and whether the examination was for diagnostic or treatment purposes [31].

Ever since the discovery of X-rays, diagnostic imaging has been an important part of the health services and with its many different modalities and technologies constitutes an invaluable support for the diagnostics of patients today [32].

## 2.2 Diagnostic imaging

Diagnostic imaging or medical imaging is imaging of the insides of the human body for diagnostic or treatment purposes. Diagnostic imaging today encompasses several different imaging modalities. However, it originated from the discovery of X-rays by Wilhelm Conrad Röntgen in 1895 [32]. This discovery led to a rapid application of X-ray

technology in clinical medicine [33]. Until the beginning of the 1970s, the radiological techniques consisted of plain radiography (2D images), tomography and fluoroscopy [32]. These techniques were mainly used for the imaging of the skeleton and lungs and also for finding fragments in the body. At the same time, the development of contrast media extended its use to imaging of soft tissue such as abdominal organs and vessels [32]. At the beginning of the 70s, computed tomography (CT) was developed. Helical and multi-detector scanners were taken into use in the 1990s [32]. In order to image soft tissue better, other imaging technologies not using X-rays developed. Ultrasound came into clinical use in the 70s and the latest development came with magnetic resonance imaging (MRI) in the early 80s [32].

Today, more than one X-ray examination is made per person each year in Europe [34]. There were 4,265,533 examinations in Norway in 2008 (0.9 examinations per person); of these 53% were plain radiographs, a reduction from 70% in 2002. The use of CT and MRI nearly doubled between 2002 and 2008 from 11% to 21% and 7% to almost 14% respectively. The use of ultrasound did not change in this period, and remained at about 12% [29]. The same development in type of modalities used has been reported internationally, even though the examination frequency varies significantly among countries [34-36].

In diagnostic imaging, teleradiology have been used for image interpretation for many years, and teleradiology is the most common telemedicine application worldwide [13]. However, mobile radiography services and diagnostic imaging are provided through a different type of telemedicine application within the primary health service at sheltered houses and prisons, although they are mainly used in nursing homes [37, 38].

## 2.3 Telemedicine

Telemedicine as a term was developed in the 1970s and meant healing at a distance [13]. In telemedicine, information and communication technologies are used to increase access to services and information, and to improve quality of health care. Telemedicine

has a broad application, from live communication between patient and health professional to transmission of text or images [13].

WHO use the terms telemedicine and telecare as synonyms and they are defined as:

'*The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interest of advancing the health of individuals and their communities'* [13 p.9].

In telemedicine, different devices are used both at home, in care facilities, or at hospitals in order to communicate across sites. This provides a way for patients to consult their physician without leaving their home, access specialised health services at home or at their physician's office, and for health professionals on different levels of the health services to communicate and cooperate [13, 39]. The main elements of telemedicine are to provide clinical support and overcome geographical barriers with the aim of improving health outcomes [13]. In telemedicine today, there are many different technologies and services in use or under development [37, 38]. Telemedicine application is the term used to refer to an overall telemedicine intervention or service [37].

There are two basic types of telemedicine applications – synchronous and asynchronous telemedicine [13]. Synchronous telemedicine requires the individuals involved to be present at the same time for immediate information transfer e.g. videoconferencing. With asynchronous telemedicine, which is most commonly used in diagnostic imaging, relevant information can be transmitted between individuals, for example by sending images to a radiologist and receiving a report at a later time [13].

Even with the potential of telemedicine and the amount of applications available, there has been a lack of evidence on the effectiveness of telemedicine applications. These applications have often been piloted in small projects but few have reached large scale implementation [13, 37]. Several barriers to telemedicine exist: lack of knowledge, resistance to using new technology, underfunding, and legal barriers [13, 40, 41]. To

secure relevant and high quality assessments of telemedicine applications, the European Commission supported the development of guidelines for consistent assessment of the outcomes of telemedicine. The aim was to facilitate the spread of good telemedicine applications to help meet the challenges for the health services of the future. This resulted in a model for assessment of telemedicine applications (MAST) [37]. Mobile radiography as an asynchronous telemedicine application can deliver diagnostic imaging, for instance in nursing homes, as reflected in the topic of this thesis. However, like many other telemedicine applications it is not widespread in any part of the world. This thesis will use MAST in order to assess mobile radiography services, and MAST will be presented in detail later. However, when diagnostic imaging is being used in nursing homes, there is a need to define nursing homes and know what nursing home residents need from a health service.

## 2.4 Nursing homes and nursing home residents

A nursing home is a facility taking care of mainly older persons, although younger people with complex health challenges may also be residents. Nursing homes offer long-, intermediate- or short-term housing, support, and all day nursing care for persons who are unable to function independently [3]. These institutions vary in type and services offered, thus many different names are used; homes for the aged, homes for the elderly, intermediate care facilities, long-term care facilities, skilled nursing facilities, or nursing facilities. All these type of facilities are categorised under the term ‘nursing homes’ in this thesis.

There is a trend in today’s western societies, Norway included, to reduce the use of nursing homes and for people to stay at home longer. The use of home-based care and assisted living facilities is increasing. However, the most fragile people will still need to be taken care of in a facility with 24-hour care and support [3, 42, 43]. In 2017, there were 40,401 nursing home beds available in Norway [44].

Persons residing in nursing homes are referred to as 'nursing home residents' in this thesis. In 2017, 42,092 people resided in nursing homes in Norway [44]. These residents had a mean age of 82.3 years [45]. Most nursing home residents have high morbidity, several co-morbidities, and around 80% are living with dementia [42, 46-48].

Based on the morbidity of this population, there is assumed to be a higher need for specialised health services compared to the rest of the population, and acute health status changes among nursing home residents often result in transfer to an emergency department [48-53]. International studies report that cardiovascular, gastrointestinal, and respiratory diagnoses, and injuries due to falls, are the most common reasons for nursing home residents visiting the emergency department [48, 51, 53, 54]. The use of diagnostic imaging is relevant for all of these. However, plain radiography is especially relevant for fractures. Residents in nursing homes, and especially residents with dementia, have a higher risk of falling than home dwelling persons of the same age group [52]. According to von Doorn et al. [52], nursing home residents living with dementia had approximately four falls per person per year compared to approximately two falls per person without dementia per year. Further, almost 38% of the falls resulted in soft tissue damage or other injuries. However, almost 3% of the falls resulted in fractures, of which approximately 1% were hip fractures.

Previous research has shown that up to 70% of the nursing home residents visiting the emergency department were admitted to hospital [48, 51, 53]. There are three main reasons for admitting nursing home residents to hospital: diagnostics, treatment to improve function and life expectancy, or palliative treatment [47]. According to Graverholt et al. [46], 16–62% of nursing home residents are admitted to hospital for acute care every year. In a Norwegian setting there was a hospitalisation rate of 0.62 per resident per year among nursing home residents above the age of 67 years. The most common reasons for acute admittance of nursing home residents in a Norwegian setting were diseases of the respiratory, circulatory or digestive systems, and injury [46]. This is more than double the hospitalisation rate of home dwelling persons of the same age [42].

Hospitalisation would give access to specialist treatment and diagnostic tools such as imaging and advanced laboratory medicine. However, nursing home residents and especially people living with dementia may not benefit from hospitalisation in the same way as the rest of the population [47, 51, 55]. For nursing home residents, the consequences of leaving a familiar environment may be too high [16, 47, 48, 55-57], inducing onset of delirium and increased mortality [48, 49]. According to Ranhoff & Linnsund [47] hip fracture and severe anaemia are the only cases where hospitalisation would benefit most nursing home residents. For other conditions, the benefit of admittance depends on each resident's condition [47]. Based on this, the avoidance of hospitalisation of nursing home residents seems vital. Previous research has stipulated that 19−62% of hospitalisations of nursing home residents could be avoided [46, 48, 53]. To prevent hospitalisation of nursing home residents, different measures have been tried out. Strengthening the competence of the personnel at the nursing homes, structuring the work at the nursing homes, an ambulant special geriatric nurse and physician service, and vaccination [46]. However, there is little knowledge of the effects of these measures on reduction of hospitalisation [46].

Other measures may be taken in order to reduce nursing home residents' number of hospitalisations and outpatient visits, for instance, bringing diagnostic tools such as diagnostic imaging into the nursing home [14-16]. Little is known about the use of diagnostic imaging among nursing home residents. Wang et al. [58] have reported on nursing home residents' visits to the emergency department and use of diagnostic imaging. Around 72% of these nursing home residents went through diagnostic imaging procedures; of these 85% had X-ray examinations (plain radiography/fluoroscopy) and 35% had CT scans. Lærum et al. [49] described the use of imaging from nursing homes in Oslo, Norway, during 8 weeks in 2004. In this period, 51 imaging examinations were referred from 714 nursing home residents. More than 90% of the examinations were plain radiographs and fluoroscopy. Almost 4% of the examinations were CT of the head, and 2% were ultrasound examinations [49]. Thus diagnostic imaging and plain radiographs in particular seem to be a specialist service useful to nursing home residents.

Mobilising plain radiography, therefore, has the potential to help nursing home residents and reduce transfers to hospital [14-18, 23, 59].

## 2.5 Mobile radiography services

Examining persons at another location than the imaging department or centre is not a new service. In France, during World War 1, Marie Curie provided such vehicles and other equipment in order to bring the new technology of the X-rays closer to injured soldiers on the battlefield [60]. This was the first mobile radiography service.

This type of service has been called radiography on wheels, a mobile X-ray service or ambulant radiography service. However, in this thesis the term mobile radiography service is used. This is the most common term for the services in national and international publications [14-20, 23, 24, 59, 61-63].

Today, mobile radiography services are set up as a telemedicine service in several countries like Australia, Italy, Norway, Sweden, Switzerland, and the USA, and a pilot scheme has been run in Denmark. Most of these serve nursing homes, or people living at home or in sheltered housing whereas in Norway this service also covers prisons [14-22, 64, 65]. Diagnostic imaging, commonly considered a specialist health service, can thus be delivered in the primary health service through telemedicine.

Previous research showing results from local mobile radiography implementation projects has reported a reduced number of transfers to hospital, fewer hospitalisations of nursing home residents, and a reduction in healthcare costs per examination in urban areas [14, 16, 18, 23, 61-63].

For nursing home residents mobile radiography services removed the exhaustion and confusion of an examination in hospital. Examinations at the nursing home gave no negative consequences for residents [14, 18, 23, 59]. Furthermore, no residents develop delirium after an examination at home, compared to 17% of residents developing delirium after an examination at hospital [18]. Previous research also showed an increase

in the number of residents that can be examined when a mobile radiography service exists. This was reported to be caused by 10–20% of residents not being able to travel to the hospital because of their condition, or the lack of personnel at the nursing home [15, 23, 49]. In addition, reports from an Italian mobile radiography service showed that more than 97% of the persons using the mobile service were satisfied based on short waiting time, comfort, efficiency, helpful personnel, and not having to go to hospital [20].

Image quality of the examinations made in the nursing home was shown to be adequate and similar to that of examinations made in hospital. In addition, the findings in more than 80% of the examinations had consequences for the treatment given, equal to the results of examinations made in a hospital [14, 24, 66]. These findings describe mobile radiography services as instrumental in providing better health services to nursing home residents, especially on the lower to mid-level of efficacy (diagnostic accuracy, diagnostic thinking, and therapeutic efficacy) in Fryback & Thornbury's [67] model of efficacy. However, little is known about the efficacy of mobile radiography services on a societal level.

On the societal level, mobile radiography services represent a new way of organising diagnostic imaging in today's health services. Little is known of the impact that policies, legislation, and the organisation of the health services make on the implementation and use of mobile radiography services. Moreover, there is a lack of knowledge about the economic effects in larger geographical areas, and whether the use of diagnostic imaging among nursing home residents changes when mobile radiography services are implemented.

In this thesis, therefore, mobile radiography services will be explored on a societal level, using WHO's framework on integrated, people-centred health services as a theoretical framework. This framework will be discussed next but first I will present the aim and objectives of this thesis.

## 2.6 Aim and objectives

The main aim of this thesis is to explore the utilisation of mobile radiography services in nursing homes and the economic and organisational aspects of these services, and thereby contribute to the delivery of integrated, people-centred health services to nursing home residents.

To fulfil this aim the following secondary objectives were identified and explored:

- To identify the outcomes of mobile radiography services for nursing home residents and for society in general (Paper I).
- To describe the overall utilisation of diagnostic imaging in the population of nursing home residents and to explore if there are any differences between the type and number of examinations provided by hospitals with and without mobile radiography services (Paper II).
- To analyse the costs of X-ray examination and treatment of nursing home residents in a societal perspective (Paper III).
- To identify success criteria and barriers in the process of implementing mobile radiography services from the hospital and municipal manager's point of view, using the following research questions:
    i. What do managers in municipalities and hospitals experience as success criteria in the implementation of mobile radiography services?
    ii. What do managers in municipalities and hospitals experience as barriers to implementing mobile radiography services? (Paper IV)

# 3 Theoretical framework

## 3.1 Person and people-centred health services

Person-centredness, efficient use of new technology, and integration of services have been pointed out as important factors in enabling the health services of the future to tackle the challenges of demographic changes [4, 8, 9]. Modern medicine has been profoundly disease oriented and because of this, there has been a tendency towards fragmentation of the health services [9]. This fragmentation has taken place within and between sectors and levels of health services, and resulted in both structural and financial barriers between primary and specialised health services [4, 68]. In order to break down these barriers, a more person-centred health service focusing on people's needs is being developed worldwide [4, 9, 11, 69-71]. Person-centredness in modern healthcare is thought to originate from the work of Carl Rogers on a person-centred approach to psychotherapy. However, its thoughts and values can be traced as far back as the thinking of ancient eastern (Chinese and Ayurvedic) and western (Greek) philosophers about what a person is [11]. Person-centred healthcare is based on the principles of human rights and dignity, participation and empowerment, and equity in access [9, 11]. In addition, person-centred healthcare is delivered without discrimination and in a partnership where healthcare providers and receivers are equals. Thus person-centred health services should be organised, managed and delivered with individuals, communities, and whole populations at the centre of the health service [9, 11].

As this thesis takes a macro-level approach to mobile radiography services, there is a need for a framework on person-centred health care on the macro level. Even stringent person-centred healthcare theories address all levels of health services. The person-centred approach to health services has been further developed especially for the macro level through the WHO framework on integrated, people-centred health services. Through this framework, health services in all United Nations member states should be organised and managed in order to be able to meet people's needs [9, 11]. In my thesis, this framework will be used to explore mobile radiography services' contribution to

developing people-centred services for nursing home residents in Norway, and to examine whether the Norwegian health services enable people-centred services to develop.

## 3.2 The WHO framework for integrated, people-centred health services

WHO introduced the framework for integrated, people-centred health services in 2016 [9]. The vision of this framework is:

'*All people have equal access to quality health services that are co-produced in a way that meets their life course needs and respects their preferences, are coordinated across the continuum of care and are comprehensive, safe, effective, timely, efficient, and acceptable and all carers are motivated, skilled, and operate in a supportive environment*' [9 p.4].

The term 'integrated health services' is defined by WHO as health services that are in accordance with the patient's needs and are coordinated across care sites and levels within and beyond the health sector [9]. Furthermore, the term 'people-centred services' is defined by WHO as health services organised around the comprehensive needs of people rather than individual diseases. Social preferences, taking into account not only the patient and carers but also the families' and communities' perspectives are respected [9].

The WHO framework has five strategies, with two to six strategic approaches in each strategy [9]. The framework is presented in Figure 1.

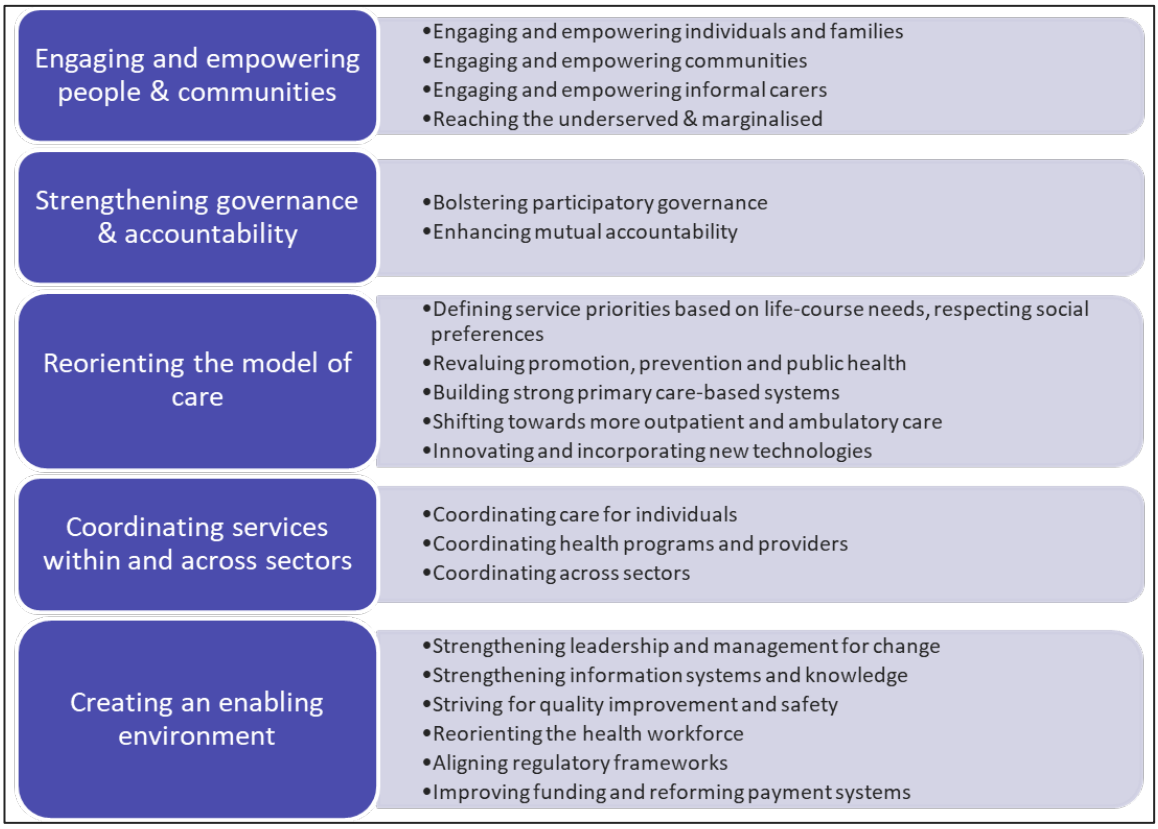


Figure 1: *The strategies and strategic approaches of the WHO framework on integrated, people-centred health services* [9].

Three of these strategies are considered especially relevant in this thesis: reorienting the model of care, coordinating services within and across sectors, and creating an enabling environment. More details on these three strategies and relevant strategic approaches are presented in Figure 2.


*Figure 2*: *Strategies three-five of the WHO framework on integrated people-centred health services [9] with appointed strategic approaches considered especially relevant for this thesis.*

According to WHO, the model of care will be reoriented to ensure that efficient and effective health services are developed and provided where community care services and the co-production of health are prioritised in line with this framework [9]. Furthermore, WHO calls for health services that are holistic and give comprehensive care that supports

people's health and well-being, and at the same time respect gender and cultural preferences. Holistic and comprehensive health services take into account the person in need of care biologically, socially, psychosocially and spiritually as well as their proximal context (e.g. family, work, financial situation) and distal context (e.g. community and cultural background) thus treating the person, not just the disease [10, 72]. Via this reorientation, WHO wants systems to be based on primary care. Consequently, primary care should be strengthened, and the specialist health services should become even more specialised, carrying out only the most complicated treatments [9]. WHO emphasises the importance of balance between primary and specialised care, recognising the important role of each level of care, and deciding which tasks belongs where within the system [9]. Moreover, WHO calls for more outpatient or ambulant patient care instead of inpatient care in hospitals [9]. Strengthening primary care and a shift towards ambulant care are aspects that are relevant in this thesis because mobile radiography service brings diagnostic imaging into primary care as an ambulant service, which could contribute to a good balance between primary and specialist care. In addition, WHO promotes the use of new technology and telemedicine for sharing medical records, reaching isolated communities and populations and facilitating patient empowerment [9]. These aspects are relevant in this thesis because a technology assessment is used in order to provide knowledge about the outcomes of new technology and telemedicine for diagnostic imaging aimed at reaching nursing home residents and helping to orient services around the residents' needs.

According to WHO, health services should be coordinated around what people need. This requires the integration of providers of health care within and across healthcare settings. Such coordination of care delivery should be aligned and harmonised through sharing information and processes among the different services. The strategy for coordination is relevant for this thesis in that mobile radiography services operate across health service levels and focus on meeting the residents' need for a familiar environment and at the same time their need for diagnostic imaging [14, 16, 23, 59]. According to WHO, there are administrative, informational, and funding gaps between levels of healthcare, and these gaps need to be bridged [9]. To be able to bridge these gaps, WHO calls for an

enabling environment in the health services [9] and emphasises the need to develop an organisational culture that supports monitoring, evaluation, and knowledge sharing across health service levels. This further emphasises the need to change the way the health services are funded and to provide financial incentives supporting integration and coordination of care across settings [9]. In addition, WHO calls for the appraisal of health services at different levels to help understand local health needs and the cost-effectiveness of alternative interventions, including health technology [9]. The development of an enabling environment is relevant for this thesis since the policies, funding systems, and development in information technology on a societal level affects the use, organisation, and economy of mobile radiography services. When examining mobile radiography services in a Norwegian context, the actions taken by the Norwegian government are highly relevant because they impact on how mobile radiography services are organised, funded and used in a Norwegian setting.

## 3.3 Norwegian initiatives for integrated, people-centred health services

In Norway there is a need to change the health services in order to provide integrated, people-centred services [5, 26, 43, 73, 74]. The current health and social care reform – the Coordination Reform – was launched by the Ministry of Health and Care Services in 2012 [5]. The main aim of the reform was to secure future healthcare services which respond to the patients' needs for coordinated services, and at the same time respond to the large socioeconomic challenges [5]. The reform aims to distribute more of the health service to the municipalities. Three of the aims of the reform are especially relevant for mobile radiography services and in line with the framework for integrated, people-centred health services: Moving services closer to where people live, transferring tasks from hospitals to the municipalities, and improving cooperation between different parts of the healthcare service [5]. These changes were to be achieved through five main actions: giving the patients a clearer role, strengthening capacity and knowledge in the

municipalities, establishing economic incentives, specialice the hospitals, and facilitating coordinated decision making in the health services [5]. According to several white papers addressing the aims of the coordination reform [26, 43, 74], a people-centred and age-friendly service should be developed, and new technology assessed and implemented. There is a need to strengthen primary care and set up partnerships across health service levels, and have a holistic healthcare policy in order to fulfil these aims [26, 43, 74]. In addition, Norway has regulations requiring dignified health care to the elderly, which are intended to guarantee a dignified, safe and meaningful old age [75]. These regulations stipulate that the health services are, for example, obliged to secure each person access to relevant health care professionals, secure continuity of treatment and care, and contribute to rehabilitation [75].

Evaluating the contribution of mobile radiography to a more integrated, people-centred health service in Norway requires a high-quality assessment of this telemedicine service [9, 37]. The MAST framework and the research methodologies used in my thesis to provide such an assessment will be presented next.

# 4 Materials and methods

Assessments of new technology must provide knowledge useful to decision-makers in order to assist managers when making evidence-based decisions [37]. In order to provide useful information to decision-makers, structure the assessment of mobile radiography services, and use appropriate research methodology, MAST was used in this thesis. MAST is an internationally recognised model for assessing telemedicine applications [38].

## 4.1 Model for assessment of Telemedicine Applications

MAST is a structured framework developed by Kidholm et al. [37] for assessing the contribution of telemedicine applications to the effectiveness and quality of care. The aim of the MAST framework is to facilitate assessments that provide relevant information to users and decision-makers who are considering using or implementing new telemedicine applications [37]. MAST was developed through the MethoTelemed project initiated by the European Commission (EC) in 2009 and was developed on the basis of the European Network for Health Technology Assessment (EUnetHTA) Core Model used for assessment of health technology [37]. As presented in Figure 3, the framework consists of three steps: Preceding considerations, Multidisciplinary assessment and Transferability assessment.

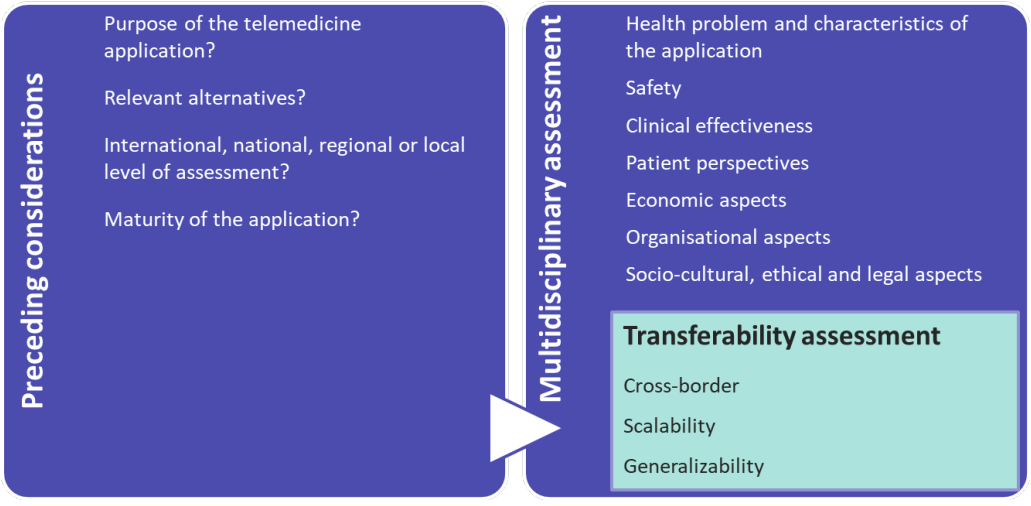


Figure 3: *The elements of the MAST framework by Kidholm et al. [37].*

At the first stage – preceding considerations – a description of the characteristics of the patient group, relevant alternatives (usual care or up-dated technology), and primary outcomes of the application should be provided. Furthermore, barriers in national or regional legislation should be assessed [37]. A rigorous literature review is recommended in the preceding considerations [76].

At the second stage, a multidisciplinary assessment should take place. This phase comprises seven domains, presented in Figure 4. In the assessment, the telemedicine application should be compared to one or more relevant alternatives. In these seven domains, it is appropriate to use different designs or methods. It is also important to use state-of-the-art methods in each domain in order to acquire valid and reliable estimates [37].

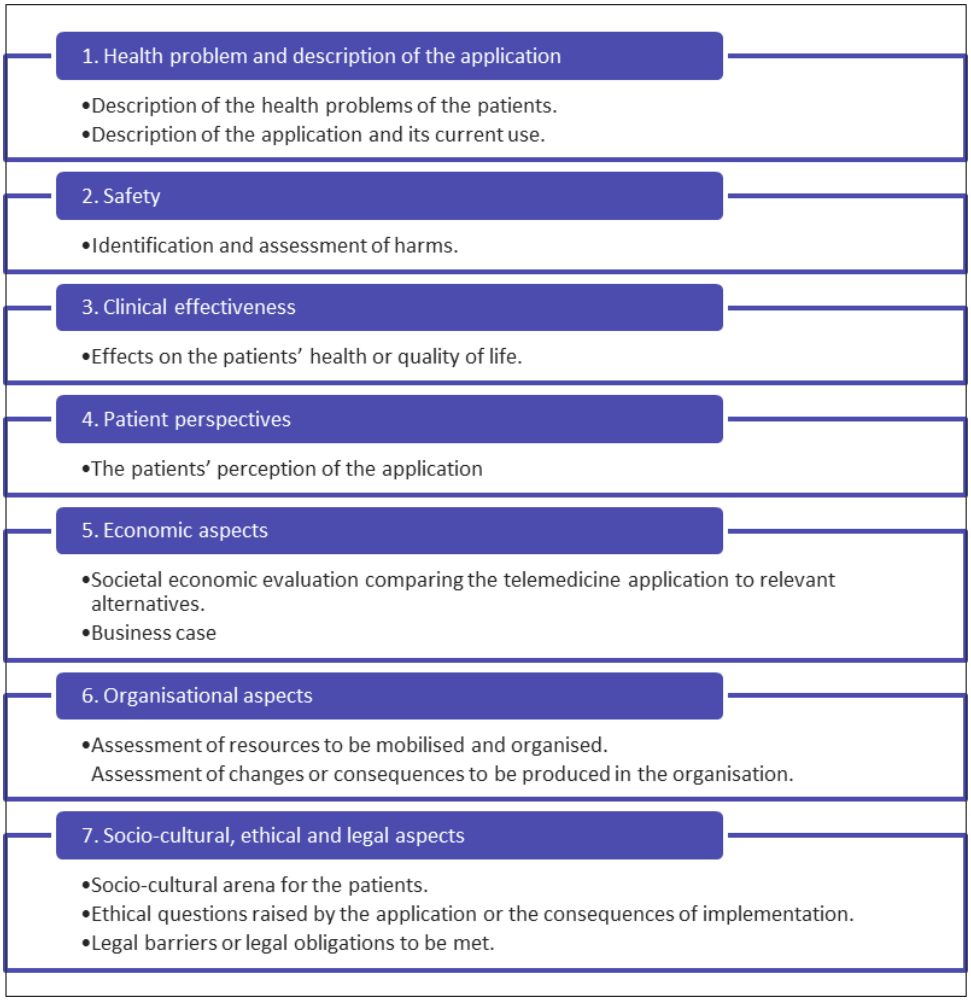


**Figure 4:** *The seven domains of MAST, developed by Kidholm et al. [37].*

The third step in MAST is the transferability assessment [37]. In order to make the results generated using MAST transferable to other technologies or countries, it is important to perform a transferability assessment. The transferability of the evaluation results of telemedicine applications from one setting to another is considered a general problem [37]. This is caused by organisational changes occurring during the implementation for instance, and the fact that the number of patients using the applications determines the costs. In addition, technical infrastructure and the possibility of integration into clinical systems differ in different countries [37].

After development, the MAST framework was empirically tested in pilots through the EC initiated project, Renewing health [38]. These pilots encountered challenges in obtaining scientific and rigorous knowledge in all seven domains, especially relevant alternatives and maturity of the application in the preceding considerations [38, 76]. The empirical test also revealed the importance at the preceding considerations stage of taking into account reimbursement and changes in the legal framework when services transition from pilots to large-scale implementation [38, 76]. However, MAST was found to be a valuable framework when assessing the effectiveness and contribution of telemedicine applications to quality of care. Moreover, it provided useful information to decision-makers considering the implementation of new telemedicine applications [38]. Consequently, it is considered appropriate to use in this study.

### 4.1.1 Research design and methods used in this thesis within the MAST framework

Within health services research, it is vital to produce reliable and valid research on which to base decisions, which further develops appropriate, acceptable, and sustainable health services [25]. Health technology assessments are used to describe a wider evaluation of health service interventions related to both the costs and the effectiveness [25]. Within this type of assessment, the general principle in MAST is that assessors must follow state-of-the-art research methods within each domain [37]. However, telemedicine services

are complex applications and thus it may be necessary to show flexibility in the choice of methods [37, 38, 76].

This study is based on a pragmatist worldview. In pragmatism, reality is both the external reality outside people's minds, and at the same time the reality within people's minds. Thus in this world view, knowledge is both constructed through individuals' experiences, and based on the reality of the external world we live in. Research is therefore always influenced by its context, for example the social and political context of the country in which the research is conducted [77]. Consequently, it is important to take into account this influence in all parts of a research project. This world view respects both qualitative and quantitative research, and the strengths and limitations of both [77, 78]. In pragmatism there is a freedom of choice of methods, techniques and procedures to best answer the research question at hand. Moreover, multiple methods could be used in order to answer a research question either in one study or when analysing a set of studies [77, 78]. Thus, through pragmatism the flexibility requested in MAST is possible, and it is appropriate for multimethod or mixed-methods research. In this thesis, a multimethod approach is used, where the methods in the studies are based on the nature of the research question applied to each domain of MAST [79].

In this thesis the MAST framework has been used to inform what domains to explore and how to explore them, with the aim of providing updated and new knowledge on mobile radiography services in nursing homes. The limited time and resources of this thesis did not allow for all of the domains in MAST to be explored.

At the preceding considerations stage (Paper I), it was shown that some domains had already been explored, such as safety, clinical effectiveness of the examinations, health problems to be met, local economic aspects, and the benefits for residents [14, 16-18, 23, 24, 49, 59, 61-63, 66, 80, 81]. Three domains of MAST in particular were identified where there was a lack of research although they were strongly linked to the societal level of integrated, people-centred health services. Thus the studies were designed in order to explore the effectiveness and contribution to quality of integrated, people-

centred health services offered by mobile radiography in nursing homes in Norway (Papers II-IV).

The domains in focus and the area assessed specifically are:

- Health problem and description of the application – the nursing home residents' use of diagnostic imaging overall and their use of mobile radiography services. Comparison of the use of diagnostic imaging in areas with and without mobile radiography services.
- Economic aspects – Costs of implementing and running mobile radiography services in a large health region, compared to hospital-based services.
- Organisational aspects – barriers and facilitators for implementing mobile radiography services within the Norwegian health services after the implementation of the Coordination Reform.

In the following, the materials and methods of the individual papers will be presented.

## 4.2 Materials and methods of Paper I

In order to explore relevant aspects of preceding considerations in the MAST framework, a systematic review of the literature was used. This was intended to give an overview of purpose, maturity, spread, previous assessments, and relevant alternatives. The focus of the review was on higher-level outcomes of mobile radiography services for nursing home residents and society. In order to get a full overview of knowledge about mobile radiography services, randomised controlled trials, non-randomised trials, descriptive studies, mixed-methods studies, socio-economic evaluations, and qualitative studies were all eligible.

### 4.2.1 Literature search

Using the P (Patient) and I (Intervention) of a PICO diagram, a search strategy was developed in MEDLINE (Ovid) and was further adapted and used in Cochrane Library, PubMed, Embase (Ovid) and Svemed+. The search strategy was made up of Mesh terms and synonyms for nursing homes AND diagnostic imaging OR radiography OR telemedicine, all with relevant adjacent terms and combinations. In addition to searching relevant databases, snowballing procedures where citations of selected papers are screened were used. Furthermore, grey literature such as economic evaluations of local projects was searched for using Google. In Google the search consisted of the following search terms: Mobile røntgentjenester til sykehjemspasienter (Norwegian) [In English: Mobile radiography services for nursing home patients], "Mobile radiology services" "nursing homes", and "mobile X-ray services" "nursing homes". Details of the search are presented in the paper and in the additional file enclosed with the paper.

### 4.2.2 Selecting records

Through the searches, 2,238 records were found. These were archived using Thomson Reuters EndNote X7.4 library. Duplicates were removed. Through screening based on titles and abstracts, 2,221 records were excluded. Seventeen records were read in full text and assessed for eligibility. A further seven records were excluded, thus 10 records were included in the synthesis.

All 10 records were assessed on methodological quality. Two tools were used for methodological appraisal: Mixed Methods Appraisal Tool (MMAT) [82] and the Critical Appraisal Skills Program (CASP) tool [83]. MMAT was used for all types of studies included with the exception of economic evaluations. MMAT has been quality assured for appraisal of qualitative, quantitative and mixed-methods studies [82]. CASP was chosen for appraisal of the economic evaluations because it is a quality-assured tool especially designed for these type of evaluations [83].

### 4.2.3 Analysis

Narrative synthesis in literature reviews based on Rodgers et al.'s guidance [84] was used to summarise and explain findings primarily from words and text in the included studies. Narrative synthesis in literature reviews is an alternative to meta-analysis when the included studies have different metodologies which make other synthesis or statistical analysis of the data from the studies impossible. In this analysis, there was first a familiarisation process with the results and characteristics of the included studies. In the familiarisation process, it is possible to acquire an overview and find similarities and differences in the studies [85]. Data were then extracted to summary tables based on Støren's methodology [86]. The following categories were included in the table: author, title and year, background, objective, research question, keywords, design, population, methods, results, conclusion, further questions, clinical implications and limitations. Data were extracted from all included records and quality was assured by 30% of the records being extracted by two people. Subsequently, content analysis was used to describe relevant data and develop categories and themes inductively from the data. In the process of content analysis, critical reflection was used when discussing data and results [84].

## 4.3 Materials and methods of Paper II

In the first dimension of MAST, it is important to describe the current use of the service and compare mobile radiography to usual service delivery. In order to assess the use of mobile radiography services in Norway today, and compare it to the use of diagnostic imaging without mobile radiography services, statistical analysis of the examinations referred from nursing homes must be performed.

### 4.3.1 Sample and data collection

Data on all examinations referred from nursing homes were requested through an invitation letter on email to 12 hospitals and hospital trusts in Norway (hereafter called hospitals). Of these, six had a mobile radiography service and six did not. The hospitals represent all four health-regions of Norway, and both urban and rural areas. One of the hospitals was a private hospital, the rest were public hospitals. Data were collected from the radiology information system (RIS) for both Papers II and III at the same time.

The following data were requested from all examinations referred from nursing homes:

- The number of examinations per NCRP code (with code name) in the year 2015
- The place of examination (at which hospital or nursing home)
- The name of the nursing home the examination was referred from

Eleven hospitals delivered data included in the study. Ten delivered full datasets and one delivered data on the mobile radiography service alone. In the area in which the hospital delivering partial data is situated, there was another hospital without mobile radiography services that delivered a full dataset. These were combined to represent the geographical area in question. Thus five hospitals without mobile radiography services and five areas represented by six hospitals with mobile radiography services are included in this study.

Data were sorted into one master excel sheet with all data per code in rows. The codes were sorted by modality (CT, MRI, Nuclear medicine, Radiography, Ultrasound and Other). The names of the hospitals were given in the columns of the sheet. For the hospitals with mobile radiography services, the examinations done at hospital were presented in a column separate from examinations made in nursing homes.

As there is no information on the individual level in the data, the number of available beds in nursing homes was used as a proxy for residents. Data on nursing home beds available were derived from Statistics Norway [44]. The hospitals included in this study covered 24,805 nursing home beds, and of these 14,500 were in the areas where mobile radiography services are available. However, 14% of these beds are not covered by the

mobile radiography service. This is because the mobile services do not cover all municipalities associated with the hospitals.

### 4.3.2 Statistics

In order to describe the use of diagnostic imaging, descriptive statistics were used. Examinations were divided into six categories – CT, MRI, Plain radiography, Ultrasound, Nuclear medicine and Other (including fluoroscopy, interventional procedures and mammography). Additionally, in order to compare the use of diagnostic imaging with and without mobile radiography services present, the data were sorted into two categories, with and without mobile radiography service. R (R Core Team, 2018) was used to perform 2-tailed Chi-square tests of difference of proportion on the use of diagnostic imaging. P values $<0.05$ were considered significant.

### 4.3.3 Ethics

The Norwegian Centre for Research Data (NSD) approved the handling and storage of personal information in this study (15.02.2016, id: 45571). The Regional Committees for Medical and Health Research Ethics (REC) approved dispensation from professional secrecy (12.02.2016, Project no. 2468). In addition, each hospital's local research committee approved the data collection in their hospital.

## 4.4 Materials and methods of Paper III

In order to explore the economic aspects of mobile radiography services as described in the fifth dimension of MAST, a cost analysis was used. The cost-analysis took a societal perspective, as recommended in MAST, in order to assess the overall economic effects in southeast Norway.

### 4.4.1 The decision tree

To model the costs of the two alternative service organisations, a decision tree was constructed in TreeAge (TreeAge Pro 2017, R2.1. TreeAge Software, Williamstown, MA; software available at *http://www.treeage.com).* The decision tree illustrated in Figure 5, included two service organisation alternatives that were to be compared: Hospital-based service and hospital-based service combined with mobile radiography service. These alternatives were based on a review of the literature [14-18, 23, 63].

In hospital-based service alone alternative, there is a possibility of residents not being able to have an examination, even though the examination would be appropriate. In these cases, treatment would be given in the nursing home without the support of diagnostic imaging [14, 15, 23, 49, 62]. For residents examined, if treatment is needed it can be given either in hospital or at the nursing home. In hospital, treatment can be given as either in- or outpatient treatment [14, 15, 23, 49, 62]. Further details on the development of the decision tree are presented in the paper.

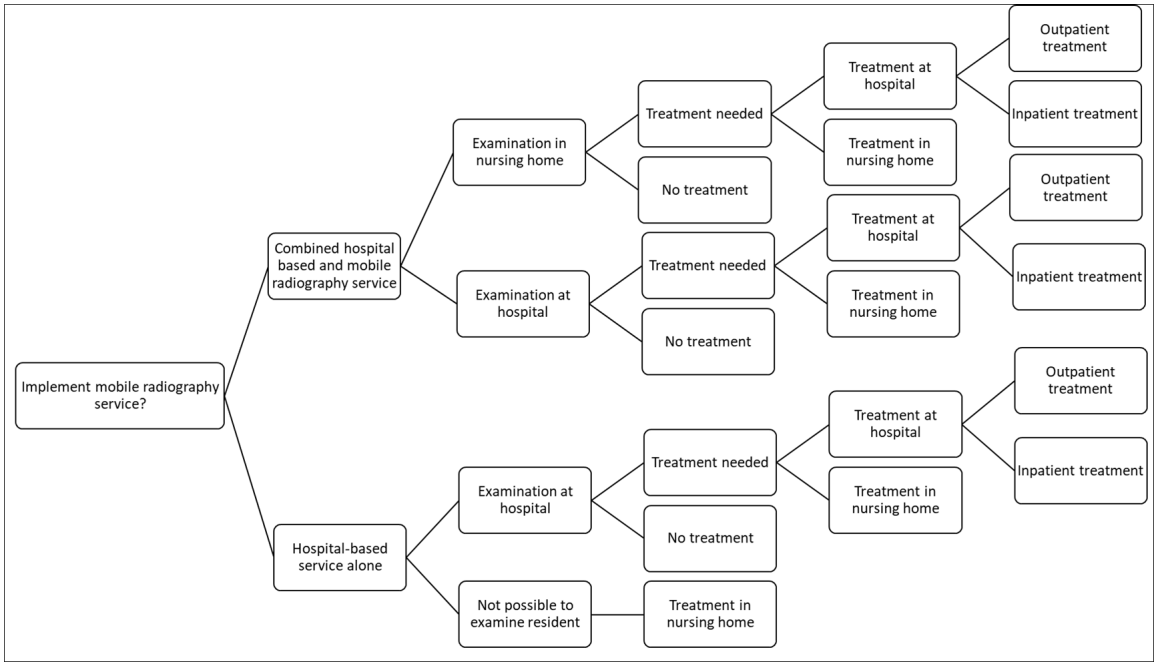


**Figure 5:** *A sketch of the decision tree, with the two alternatives and the possible events in the different branches of the decision tree.*

### 4.4.2 Data collection and populating the decision tree

#### *4.4.2.1 Probabilities*

Data on probability of the events in the decision tree were collected from earlier research and the RIS-data described under Paper II. However, only the data on plain radiography in seven hospitals within the south-eastern health region was used. Probability of examination and place of examination came from the RIS data, while method of transportation, treatment needed, place of treatment, and type of treatment were collected through the literature search [14, 23, 49, 66]. All probabilities were, entered as beta distributions when appropriate in order to account for uncertainty. A beta distribution is a continuous probability distribution which can only vary between 0 and 1, thus appropriate for probability parameters [87]. Details on the probabilities used are published in the paper.

#### 4.4.2.2 *Costs*

Data on costs was requested from hospitals by email, for example the cost of ambulance transfer, imaging examinations, and mobile radiography service equipment. In addition, the place of examination and name of the nursing homes from the RIS-data were used to calculate travel distance. The costs of taxis and labour were derived from Statistics Norway [88, 89]. The cost of hospital treatment was calculated from the Norwegian diagnosis related groups system (DRG) [30]. Furthermore, the cost of treatment in the nursing home and medical examination, other types of information e.g. time spent on different tasks and person accompanying residents were obtained from the literature [23, 90-92]. All costs are based on 2016 Norwegian kroner, and converted to Euro (€) by using the 2016 average currency rate (9.2899) for publication internationally. All cost parameters were, whenever possible, entered as gamma distributions. A gamma distribution is restricted to be between 0 and +∞. This is appropriate since costs can never be negative [87]. Details of costs included in the model are published in the paper.

### 4.4.3 Statistics

Descriptive statistics in SPSS (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp) were used to calculate the 95% Confidence Interval and Standard Deviation of the cost and probability parameters used in the decision tree.

In order to evaluate the impact of parameter uncertainty, probabilistic sensitivity analysis (PSA) was used [87]. PSA was run as Monte Carlo Simulations in TreeAge, which takes into account the uncertainty of all the parameters at the same time, and simulates their combined effect on cost difference [87]. SPSS was also used to do paired-samples t-test to compare the results of the PSA for significance of difference.

## 4.5 Materials and methods of Paper IV

In order to explore organisational aspects of mobile radiography services, barriers and facilitators for implementing mobile radiography services were chosen as a focus. These topics were in focus because of the relatively small distribution of the mobile radiography service despite earlier research showing it to benefit the residents and reduce healthcare costs.

### 4.5.1 Sample and procedure

This study used volunteer sampling. Managers from both hospitals and municipalities in areas that had implemented or were in the process of implementing mobile radiography services during the last 10 years were eligible to participate.

- At hospital: departmental (X-ray department) or executive managers.
- In a municipality: administrators of health services, or managers of nursing homes.

Based on these criteria, representatives from five hospitals with associated municipalities were eligible to participate. An invitation with inclusion criteria and the participant information letter was distributed by email to relevant hospitals and municipalities.

Participants volunteered by emailing a contact person. For participants who met the inclusion criteria, a time and place for the interview was arranged. Five hospital managers and six municipal managers were included in the study. Detailed information on the participants is presented in the paper.

### 4.5.2 Interview guide

Based on the systematic literature review in Paper I, a semi-structured interview guide was developed based on Kvale & Brinkmann's methodology [93]. The interview guide was tested in two pilot interviews for quality assurance. After evaluation, the pilot interview and the interview guide were assessed as appropriate and functional. Thus the two pilot interviews were included in the study. The interview guide is available in the additional file attached to the published paper.

### 4.5.3 Data collection

The interviews were carried out at a time and place of the participants' choice. All interviews took place at the participants' workplace in their office, in a meeting room or in the cafeteria at the hospital. The interviewer gave information on the project and written consent was given by participants before the interview commenced. Most of the interviews lasted from 45 minutes to 1 hour with the exception of one shorter interview where the manager was not involved directly in the process of implementing mobile radiography services. All interviews were audio recorded using two Zoom H1 Handy Recorders. One researcher carried out all the interviews. In three interviews, another researcher sat in for quality assurance of the process. In all interviews, notes were made on main topics and first impressions or thoughts arising during the interview. As far as

possible, the interview guide was adhered to in all interviews, in order to ensure that all topics were discussed. The interviewer summarised the main statements made at the end of each interview in order to reach consensus [93]. Directly after finishing the interview, impressions and thoughts on the interview and the interview setting were noted in order to secure these for later analysis. Moreover, notes on what to do or not to do in the next interview were made in order to learn from the interview processes.

### 4.5.4 Analysis

Framework analysis as described by Ritchie [85] was chosen in order to have a systematic inductive-deductive approach to the analysis. In addition, the analysis was team based. Team-based framework analysis was based on Gale et al.'s [94] method for the analysis of qualitative data. This analysis method has seven stages. These stages and how these were used in this study are described in Table 1.

**Table 1:** *The seven stages of team-based framework analysis for thematic analysis as described by Gale et al. [94], and the activities used in this study.*

| Stage | Activity |
|---|---|
| Transcription | Verbatim transcription was done within the same or next day after the interview. |
| Familiarisation | After all interviews were transcribed, the transcript was read through to get an overview of its content and themes discussed. |
| Coding | Two researchers coded three transcripts using open coding. |
| Developing the working analytical framework | Coding and codes were discussed in an analysis team meeting. Codes were grouped into categories and this made up a working analytical framework. In addition, important quotes were identified.<br><br>New transcripts were coded using the framework and open coding, and this process was repeated (illustrated below) until all transcripts were coded and a final framework of codes was agreed upon. The final framework is available in the additional file of the published paper. |

| | |
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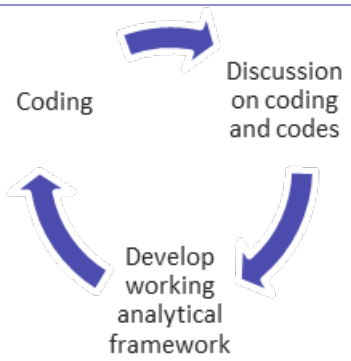
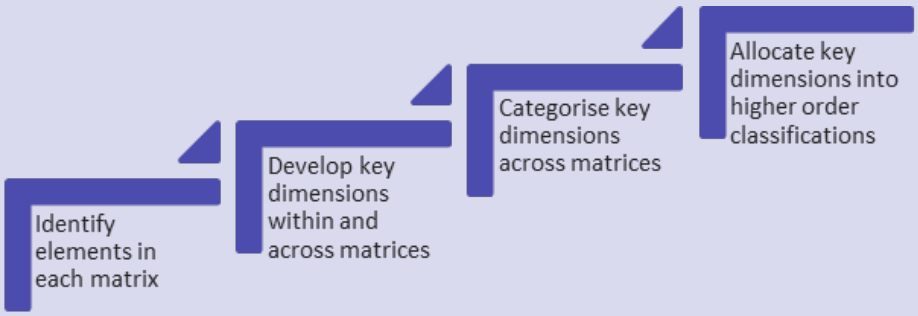
| |  |
| **Applying the analytical framework** | All transcripts were indexed with the final framework using QSR International's NVivo Pro version 11 software (NVivo).<br>Important quotes were marked with a star and indexed. |
| **Charting data into the framework matrix** | In NVivo, 33 matrices were developed based on the framework, and data were charted into the matrices. Short summaries were charted into corresponding cells in matrices where codes are columns and participants are rows. |
| **Interpreting the data** | Descriptive thematic analysis was conducted as described by Ritchie [85]. The analysis team agreed on a research question for the analysis. 'What are the success criteria and barriers when implementing mobile radiography services in nursing homes, from a manager's perspective?'<br>The next steps in the analysis are illustrated below. This was a back and forth process, with discussions in the research team throughout.<br>  <br>After the final higher order classifications and key dimensions were agreed upon, results were written out, supported by key quotes. The contents of the elements, key dimensions and categories are available in the additional file of the published paper. |

### 4.5.5 Ethics

The Norwegian Centre for Research Data (NSD) approved the handling and storage of personal information in this study (id: 45739, 04.01.2016). NSD considered approval of this study by the Ethical Committee to be unnecessary. A letter with information to

participants and a participant consent form was developed. These was approved by NSD. In this study, third party information could be given during the interviews. All possible measures was taken to prevent the recording of information on third parties. In addition, all information on third parties is anonymised in publication.

# 5 Main results

The main results of each of the four papers in this thesis are summarised in this section. Further details on results are presented in the respective papers.

## 5.1 Main results Paper I

Through narrative analysis of the ten included articles in this systematic review, seven outcomes of mobile radiography services were identified. These were sorted into three different categories. The categories affect each other and are on different levels.

Three overarching outcomes were identified. (1) Reduction in hospitalisations, outpatient examinations, and treatments. (2) Reduced number of transfers between nursing home and hospital, and reduced waiting time outside of the nursing home. (3) An increase in access to X-ray examinations. The outcomes in this category were found to explain or influence the outcomes in the other categories – resident, and societal outcomes.

There were two resident outcomes. First, the effects on the overarching level reduced negative consequences of the process of carrying out an X-ray examination for the nursing home residents. This reduced the number of residents who were exhausted, confused, or developed delirium. Second, the X-rays impacted on the treatment and care of up to 85% of these residents. Thus increased access on the overarching level gave more adequate treatment and care when the assumed diagnosis is supported or disproved by an X-ray examination.

There were two societal outcomes. These outcomes were most likely affected by both the overarching outcomes and the resident outcomes. On the societal level, resources were used more efficiently because ambulances did not need to transfer these residents unnecessarily, and healthcare personnel from the nursing homes could use their time in the nursing home instead of in the waiting room at the hospital. In addition, the reduced negative consequences for the residents would probably free nursing home personnel to take care of other residents. An efficient use of resources would further lead to reduced costs. Local projects calculated a 30–60% cost-reduction per examination.

## 5.2 Main results Paper II

Statistical analysis of RIS-data from 11 hospitals from all parts of Norway showed an underuse of diagnostic imaging among nursing home residents. Despite the high morbidity in this population, less than 0.5 diagnostic imaging examinations were performed per person per year compared to almost 1.0 for the population in general. Of more than 11,000 examinations reported in this study, 87% were plain radiographs, 8% CT and 4% ultrasound examinations. Other modalities were seldom used – ≤1%.

When comparing areas with and without mobile radiography services, a significantly larger proportion of diagnostic imaging procedures were demonstrated in areas where the mobile radiography service existed. The difference in proportion was due to a large and significant difference in the proportion of plain radiographs. Where available, >73% of the plain radiographs were carried out by the mobile radiography service. When comparing the use of CT and ultrasound, there was a significantly lower proportion of examinations by these modalities in areas with a mobile radiography service.

Within the modalities, chest, hip and pelvic examinations was most frequently used in plain radiography (62%). In CT, brain and the abdominal/pelvic area were most commonly examined (65%). In ultrasound, the abdominal area was commonly examined as well. However, the most frequent examination was of the veins of the lower extremities. Together these constituted 69% of the ultrasound examinations performed.

## 5.3 Main results Paper III

Through cost analysis in a decision tree, a significant cost reduction was shown when mobile radiography services were used combined with hospital-based imaging. A mean cost of € 1,946 for examination and treatment of one nursing home resident was found when mobile radiography services exist, compared to a mean cost of € 2,790 without. Through 1000 Monte Carlo simulations the PSA showed a cost reduction was found in all cases, and would most probably be € 560–€ 1,080 per resident. Through a paired t-test,

the mean cost reduction of € 844 with a 95% Confidence Interval ranging from € 837–€ 851 (SD=112.4) was shown to be significant, p <0.001. This results in a mean cost reduction of 30% in southeast Norway, amounting to a cost reduction of more than €6,220,000 per year.

## 5.4 Main results Paper IV

Through 11 semi-structured interviews with managers from both hospitals and municipalities, barriers and facilitators for implementing mobile radiography services were explored. Barriers and facilitators were identified on three levels: macro, meso and micro levels. At the macro level, barriers and facilitators were found in national, regional and municipality health policies and conditions. These included the national reimbursement system, funding, organisational changes, and local policies. At the meso level, inter-organisational implementation projects represented the main category. Within this category, economy, planning, collaboration, procedure development, and piloting and evaluation were the main topics. At the micro level, the personnel's experiences with the service, and the professionals' skills and personal characteristics were main topics.

Three main categories of barriers for implementing mobile radiography services were found: financial, structural, and procedural. Financial barriers were identified as the national reimbursement system, where mobile radiography did not have a designated code for reimbursement, and the need for allocating money over the budget in several organisations. The structural barrier was the lack of management across the organisations. In the procedural barriers category, lack of electronic communication between hospitals and nursing homes, and unavailability of wireless image transfer from the X-ray machine to the hospital were the main identified barriers.

Despite the substantial barriers that occurred in the implementation process, all projects succeeded. The success criteria for overcoming financial barriers were external funding, budget negotiations, and contracts between hospitals and municipalities. To overcome

the structural barrier, the success criteria experienced by managers included networking, time dedication, piloting, information, and inclusion of users. To overcome the procedural barriers, the success criterion was to set up manual routines to compensate for the lack of electronic and wireless communication.

# 6 Discussion

To develop integrated, people-centred services there is a need to assess the different parts of the health services [9]. This thesis is such an assessment of mobile radiography services in nursing homes. The aim of this thesis was to explore utilisation of mobile radiography services in nursing homes, and the economic and organisational aspects of these services, and thereby contribute to the delivery of integrated, people-centred health services to nursing home residents. However, the quality of the assessment affects the validity of the conclusions, therefore I will start with a discussion of methodological strengths and limitations. I will then discuss how mobile radiography services can contribute to integrated, people-centred services, and how societal conditions affect the implementation of telemedicine applications such as mobile radiography in the Norwegian health services.

## 6.1 Methodological strengths and limitations

In this chapter, the strength and limitations of the methodologies and the study samples used in this thesis will be discussed. In person-centred research, research should be conducted for or with participants or persons rather than on persons as objects [11]. Research in this thesis was conducted for the nursing home residents. Thus the findings may contribute to a better and more person-centred health service for nursing home residents.

### 6.1.1 The use of the MAST framework

With mobile radiography services being a telemedicine application, the use of MAST to guide the work in the thesis seems appropriate [37]. MAST was designed to provide knowledge on telemedicine applications' effectiveness and contribution to quality of care so that managers could decide whether or not to use new telemedicine applications. As

a result, this contributed to more large scale implementation of the most efficient and cost-effective alternatives [37]. The knowledge gaps and domains to explore were identified at the preceding considerations stage with a recommended systematic review of current knowledge on mobile radiography services, [37, 76]. The review of the literature in Paper I was exhaustive and thus gave a good overview of the field. However, the quality of the conclusions made relies on the level of confidence in the included studies [95]. In addition, including studies of different methodologies made a meta-analysis impossible, thus narrative synthesis of the textual description of the results was chosen in order to identify common topics and different studies' input on these. The number of studies included in the literature review conducted at the preceding considerations stage was limited, and the studies were mostly related to successful implementations of mobile radiography services in local projects. Thus there may have been a bias towards positive outcomes of mobile radiography services, caused by the success of these implementations. Furthermore, there was a variation in the quality of the knowledge in the papers included in the review. In addition to grading their contribution in the main findings, this grading contributed to identifying which domains needed to be researched further. Nonetheless, the systematic review gave an overview of current knowledge and a guideline for choosing which domains to explore in this thesis. The three domains chosen were based on time and resources available, and the societal perspective of the study. In addition, some domains had already been explored to some extent, such as safety, clinical effectiveness of the examinations, health problem addressed, local economic aspects, and the benefits for residents [14, 16-18, 23, 24, 49, 59, 61-63, 66, 80, 81].

MAST calls for state-of-the-art research methods to be used in each domain [37]. However, this has proven difficult in other projects using MAST [76]. Moreover, in each domain the transferability of the studies was addressed in order to produce papers of interest to an international audience. However, the political, economic, and geographical conditions of Norway may be very different from many other countries, thus transferability may be challenging. To facilitate the use of state-of-the-art methods in all domains, and for results to be transferable, a multimethod design was applied in order

to achieve the main aim of this thesis. Using a multimethod design to answer one research question lies within the pragmatist world view whereby the best possible research method should be chosen for each research question. Multimethod research exploits strengths from the different methods used but also contains the limitations of the different methods [79]. The use of a multimethod design in this thesis included the use of two separate samples: examinations referred from nursing homes and managers in hospitals and municipalities implementing mobile radiography services. The sample of examinations referred from nursing homes was used in two quantitative analysis in this thesis, while the sample of managers was used in the qualitative study. In the following, the strengths and limitations of the quantitative methods used will be discussed before discussing the strengths and limitations of the qualitative method used.

### 6.1.2 Quantitative approaches

The first sample – the examinations referred from nursing homes – was included for an extraction of data from the hospitals' RIS. These data were used to explore the utilisation of diagnostic imaging among nursing home residents as well as to calculate the probability of being examined in the nursing home and travel distances for the cost analysis. The data did not include any personal information. Thus consent was not considered necessary. However, the data collection required dispensation from professional secrecy, which was granted by REC. Data handling was approved by NSD before the data collection started. These approvals were necessary because of the possibility of indirectly identifying individual residents.

#### *6.1.2.1 RIS data in statistical analysis*

In the assessment of utilisation of diagnostic imaging among nursing home residents in Paper II, statistical analysis of RIS data was considered the appropriate method. All four health regions were included in order to compensate for differences in travel distance and referral rates. Data were requested in the NCRP code system used by all hospitals to

ensure that the same examinations were compared from all hospitals. However, hospitals could interpret the coding system differently. The data included examinations referred from nursing homes only, and include the name of the nursing home and where the examination took place. Consequently, this constituted a good basis for comparing the use of diagnostic imaging among nursing home residents with and without a mobile radiography service present, and for comparing the data with studies on the use of diagnostic imaging among the general population. The data also provided a more comprehensive picture of the use of diagnostic imaging and mobile radiography services among nursing home residents in Norway than earlier analysis using data from one hospital only [62, 63]. In datasets delivered from hospitals, examinations might be missing, and nursing home residents might be registered at their home address and referred from a doctor not employed at the nursing home. This meant that they were not registered as a nursing home residents in RIS. These examinations would then not have been reported. The proportion of examinations missing for this reason, or whether the proportion is equal in all hospitals or areas is unknown. This could lead to an under-estimation when comparing these data with utilisation in the general population. Furthermore, the data did not include information on an individual level so it was not possible to calculate the use of diagnostic imaging per person. In order to compensate for this, the number of nursing home beds was used as a proxy for residents. This may have led to an under-estimation of examinations per person, because more than one person could occupy one nursing home bed during the course of a year. This is due to residents dying or short-term stays. Nonetheless, this gives an indication of the use among nursing home residents and compares categories that are as similar as possible.

#### *6.1.2.2 Decision tree model*

In a societal perspective, decisions on resource allocation should be based on all relevant evidence including its uncertainties. In MAST, a cost-effectiveness analysis is preferred regarding the economic aspect [37]. However a simpler cost-analysis was used in Paper III. A cost-analysis was chosen based on the data available. No data were available on

quality-adjusted life years (QALYs) of nursing home residents in Norway in general, for instance, or the changes in QALYs after an examination either in hospital or at a nursing home. Thus effects such as reduction in hospitalisation and transfers to hospital are described narratively.

Since interactions between residents in the model were not considered relevant, the timeframe of the model is relatively short, and recurrence of the event is not relevant, a decision tree model is considered appropriate [87, 96]. The strength of a decision tree model is that it is simple to develop, it is transparent, and easy to interpret. In addition, evidence from many sources relevant for the decision are taken into account [87, 96]. However, decision models have limitations [87, 96]. A model is a simplification of reality. You need to make choices on what to include in the model; many details must be included in the model in order to take all relevant costs and events into consideration [87, 96]. In order to make a good model, there is need for as much real data from good quality studies as possible. In the case where real data do not exist or are scarce, you need to make assumptions or use the best data available [87, 96]. First the relevant alternatives must be set up with mutually exclusive pathways, each with their probabilities. The probabilities are calculated from current knowledge. For instance, in the model used in this thesis, the use of RIS data secures the addition of real data to the model [96]. Data did not exist for other parts of the model, for instance hospitalisation rates for patients being examined at hospital when the mobile radiography service exists. Thus the hospitalisation rate was assumed to be the same as for examinations made in hospital when mobile radiography services do not exist. This could lead to an under-estimation of hospitalisation for residents examined in hospital when mobile radiography exists because in this case, residents are most likely transfer to hospital when they are acutely ill or in need of surgery. Thus the model consists of both real data and assumptions all with their uncertainties. It is a strength, however, that through the use of PSA, all these uncertainties are taken into account in the decision tree model.

The quantitative approaches for assessment of costs and use of mobile radiography services have now been discussed. In order to assess organisational aspects through

managers' experiences of barriers and facilitators for the implementation of mobile radiography services, a qualitative approach was considered appropriate.

### 6.1.3 Qualitative thematic content analysis

A qualitative approach was considered appropriate based on a limited number of managers available as participants. Furthermore, there was a need for breadth and depth in the data to understand the different barriers and facilitators experienced by these managers. This sample consisted of a few managers who had been or were involved in the implementation of mobile radiography services. Managers from both municipalities and hospitals having implemented mobile radiography services in the last decade were included in individual semi-structured interviews. The sample consisted of both male and female managers, managers with different length of experience as managers, and from different levels of management. This mixture of managers from different organisations was important in order to ensure breadth in the data [97]. Having managers who were all involved in successful implementation of mobile radiography services may lead to a bias toward positive experiences of mobile radiography services. However the topics discussed in the interview required the participation of someone involved in the process in order to get depth in the data [97, 98]. Although including managers with experience of failure to implement mobile radiography services would have added to the depth and breadth of the data, to the best of my knowledge there has been no such project in Norway.

A semi-structured approach was used in order to ensure that all relevant topics were discussed with all managers. We used open-ended questions to encourage the managers to talk freely about their experiences of barriers and facilitators for mobile radiography services [93, 99]. However, the semi-structured approach could prevent the participants from talking about other topics that might be relevant from their point of view, thus restricting the depth and breadth of the data one would get from a unstructured

interview [99]. However, the use of the semi-structured approach was considered appropriate because it was important to include all topics in all interviews [99].

#### *6.1.3.1 Preparation phase*

In order to fulfil criteria for trustworthiness in qualitative studies, commitment to the topic and knowledge of the context in which managers have implemented mobile radiography services are important [97, 98]. My commitment to the subject comes from reading theory and previous research as well as from experience of working in a nursing home in different diagnostic imaging departments, cooperating with managers in the health services for several years, and my grandmother being a former nursing home resident living with dementia. All these perspectives have brought insights useful to understanding the context in which these managers have implemented mobile radiography services [97]. However, previous knowledge and experience also create the need for reflexivity throughout the process of a qualitative study [97, 98]. It is important to discuss and be aware of the understanding you bring in, and how this affects the questions asked and the analysis process of the data [97, 98]. In order to take into account the effects of the pre understanding of the researcher, interviews were piloted and reflexive discussions was used in the planning of the interviews. Further, the participants volunteered, and participated under informed consent. Pilot interviews were conducted in order to allow managers of the participant group to co-create themes in the interview guide and give input to the interviewer on the interview process. Thus they collaborated in developing the interview guide and the interview method. The managers chose the time and place of the interview. In addition, at the end of the interview, a summary of the main topics discussed was made in order for the managers to give corrections or clarifications in the interviewer's perception of their statements. All these measures were carried out in order to conduct person-centred research with persons not personally benefitting from the outcome, with a sensitivity to the context and in dialogue with the participants. This is crucial in person-centred research [11].

#### *6.1.3.2 Analysis and report phases*

Rigorous and transparent methods should be applied in the analysis of qualitative data [97, 98]. The team-based framework method was applied rigorously in the analysis of the data, and this process was described in detail in the paper to ensure a transparent analysis process [97, 98]. A clear analysis process is important in order for other researchers to be able to repeat the study in a different context, and be able to assess the trustworthiness of the study [97, 98]. The framework method supports a clear path between data and findings [85, 94]. Reflexivity is just as important in the analysis process, as in the preparation phase. As part of the team-based analysis process described by Gale et al. [94], reflexivity discussions of coding and abstractions in the analysis process are important in order to be aware of the characteristics and experiences of the researchers' influence on the process [94, 97, 98]. Furthermore, preliminary findings were presented at research seminars in order to test the impact and importance of the findings for society and the health services, [97, 98], and input from these seminars was used to refine the analysis.

In reporting results in Paper IV, findings and quotes needed to be translated from Norwegian to English. The interviews were carried out in Norwegian and thus all data and analysis of data took place in Norwegian. When translating quotes, categories and classifications, there is the possibility of losing or adding meaning in translation [100]. In order to reduce the effects of translation, as recommended by van Nes et al. [100], Norwegian was kept as the analysis language until writing the report. In addition, a professional translator was used in close collaboration with the analysis team in order to avoid changes created in the translation of quotes, categories and classifications.

Notwithstanding its limitations, the design and methods of this thesis have led to new and relevant knowledge on mobile radiography services in nursing homes. How mobile radiography services can contribute to integrated, people-centred health services will be discussed next.

## 6.2 How mobile radiography services can contribute to integrated, people-centred health services

In this section, the empirical findings of this thesis will be discussed with a people-centred perspective on health services within a Norwegian context through the WHO framework and the Norwegian healthcare policy. This thesis explores mobile radiography services in a societal perspective. Thus it is considered appropriate to use the integrated, people-centred health services framework since this is the current international health policy framework guiding national health policies worldwide [4, 5, 9, 26, 43, 74].

### 6.2.1 Adapting services to nursing home residents' needs

The integrated, people-centred health services framework and the Coordination Reform both aim to coordinate health services around the needs and demands of the population and each individual, unlike a disease-oriented health service where services are fragmented into disease specific departments and with disease specific approaches to treatment and care [4, 5, 9, 69, 71, 101]. In order to meet people's needs, knowledge of their actual needs are essential. As shown in Paper I, nursing home residents need to stay within a familiar environment and have a high degree of coordinated and integrated services [18, 47, 51, 55, 56, 59, 73, 102]. These needs are caused by high morbidity, several comorbidities and the fact that about 80% of these residents are living with dementia [42, 46-48]. Furthermore, Papers I and IV showed that diagnostic imaging is an important diagnostic tool for physicians when planning treatment and care for nursing home residents, particularly in relation to infections, injuries, and circulatory or gastrointestinal conditions. Such conditions are common among nursing home residents, and often lead to hospitalisation or visits to the emergency department [2, 23, 42, 46, 48, 51, 54, 55, 58].

In order to meet the comprehensive needs of this population, whenever possible the services should be delivered within the nursing home. Hospitalisations and visits to the

emergency department should be kept to a minimum [2, 14, 16, 18, 23, 42, 46-48, 50-56, 59, 73, 102]. In Paper I, the negative consequences for residents leaving the nursing home for an examination were shown. Confusion and exhaustion occur in most residents, and almost 20% of nursing home residents develop delirium after an imaging examination at hospital. Previous research also describes other negative consequences of hospitalisation for nursing home residents such as falls, bed sores, further loss of functionality, and increased mortality [47, 55]. Paper I showed that mobile radiography services reduced the number of hospitalisations and outpatient treatments in hospital. In addition, Paper IV shows that mobile radiography played an important role in keeping a person-centred culture in nursing homes. With residents staying within the nursing home instead of being hospitalised or treated in the emergency department, it would be easier to set up a holistic and continuous care and treatment plan which is in line with the vision of integrated, person-centred health service, and the coordination reform [5, 9].

### 6.2.2 Utilisation of diagnostic imaging among nursing home residents

An important principle for integrated, people-centred health services and the Norwegian welfare system is equality in access to health services [5, 9, 27]. Mobile radiography services can help to meet nursing home residents' need for familiar surroundings, and at the same time provide access to plain radiography equal to that of the general population. Papers I and III showed that 10–20% of residents in urban areas did not have access to diagnostic imaging if a mobile radiography service was not available. However, in rural areas the percentage of residents not able to travel may be even higher because the travel distance is long, thus giving these residents even poorer access to necessary imaging diagnostics. Paper II showed that mobile radiography services increased the use of diagnostic imaging among nursing home residents. However, there was still an underuse of diagnostic imaging compared to the rest of the population [23, 29, 49].

Moreover, Paper II showed that mobile radiography services changed the use of the different modalities among nursing home residents. The proportion of plain radiography examinations was more than 37% higher in areas where a mobile radiography service was available. At the same time, the proportion of CT and ultrasound examinations was about 47% and 36% lower respectively in areas with mobile radiography services. Thus mobile radiography services contribute to better access to plain radiographs for nursing home residents. Previous research from Wang et al. [58] and Lærum et al. [49, 66] showed plain radiographs to be the most common examination for nursing home residents whether or not mobile radiography is available. However this service may result in even less use of more advanced imaging.

The reduction in CT examinations may be caused by plain radiographs replacing some CT examinations in situations where a plain radiograph might be sufficient, thus some residents may have CT examinations unnecessarily when present at the hospital. However, in situations where the CT examination has been carried out as a follow-up after a plain radiograph because of uncertain findings, or CT is the appropriate modality, the residents examined at the nursing home may be treated with an inferior diagnostic certainty. The barrier for transferring residents to hospital for advanced diagnostic imaging may also increase after implementation of mobile radiography services, when it is easier to prioritise plain radiography.

The reduction in the use of CT and ultrasound when mobile radiography services exist, may point to reduced access to necessary diagnostic imaging for residents living in areas with mobile radiography services. Thus there may be a need for referral guidelines in connection with diagnostic imaging for conditions common for nursing home residents. Furthermore, there may be a need to mobilise modalities other than plain radiography in order to give nursing home residents access to imaging services equal to that of the general population. Mobile CT units in ambulances with a head scanner, currently used to diagnose stroke, have been tested in several countries [103-105]. More than 40% of the CT scans referred from nursing homes reported in Paper II were of the head. These CT ambulances could be used to examine nursing home residents as well as suspected

acute stroke patients in the general population. This could give more residents access to CT examinations. Furthermore, the mobilisation of ultrasound could be done in order to increase access to this modality within the nursing home population. Mobile ultrasound services are available at least in Sweden and the USA [106, 107]. Ultrasound equipment is easy to mobilise because of the size of the equipment. However, there is a need for a radiologist or sonographer to operate the service and the number of examinations is not as high as for plain radiography. This will affect the cost-effectiveness of this service. However, it would be possible for a sonographer with competence within both radiography and sonography to operate a combined service with plain radiography and ultrasound in the same vehicle. This could increase nursing home residents' access to ultrasound and further utilise society's resources better.

### 6.2.3 Economic aspects of mobile radiography services

Mobile radiography services may help to maintain a sustainable health service. Paper I and Dozet et al. [61] reported a cost reduction of 30-60% per plain radiography examination in cost analysis made in local projects in Norway and Sweden. However, there was a need to assess the societal perspectives on costs of mobile radiography services. Thus Paper III focuses on the costs of both examination and treatment of nursing home residents in the largest health region of Norway, covering 56% of the Norwegian population. The cost analysis showed a cost reduction on a societal level of 30% per resident examined and treated.

Among managers interviewed in Paper IV, there was a general perception that mobile radiography services were cost-effective in urban areas only. However, Paper III indicated significant cost reduction in the whole of the South-eastern health region of Norway, consisting of both urban and rural areas. One rural mobile radiography service has recently been set up in mid-Norway where the X-ray machine is used both in a local health centre and as a mobile service [108], but unfortunately no results have yet been published from this particular service. However, in Italy a similar rural radiography service

has been set up. This service reduced transfers to hospital, and increased access to imaging among persons above the age of 60 [19, 20]. Thus this type of mobile radiography service seems promising in rural areas. The managers' perception of cost reduction in urban areas only may be caused by the disease-focused and thus fragmented reimbursement per examination funding of diagnostic imaging, where the imaging departments tend to think that a large number of examinations is the most important factor for cost-effectiveness. The cost reduction shown in Paper III was mainly caused by the reduction in transfer and treatment costs rather than in the imaging department which carries most of the extra costs. In rural areas, the number of examinations per day would be low. However, the cost reduction on a societal level could be substantial, based on high transfer costs when travel distances are long [61-63]. In rural areas, it may be possible to use the mobile radiography service in combination with radiography at a local medical centre, in order to utilise the capacity of the equipment. The economic aspects are strongly connected to the organisational aspect of the health services.

### 6.2.4 Organisational aspects of mobile radiography services

Another strategic approach in the WHO framework and in the Coordination Reform is building a strong primary care-based health system and at the same time maintaining a good balance between the primary and specialised health service [5, 9]. The strengthening of primary care is a central aim in the Coordination Reform and the latest reports to the Storting on healthcare in Norway [5, 26, 43, 74]. Mobile radiography services contribute to a stronger primary care due to their resource-saving effects, shown in Papers I and IV. When nursing home residents stay within the nursing home, personnel will not have to spend their workday arranging transfers and finding someone to accompany the resident, or accompanying the residents themselves. Rather they will be able to take care of the residents in the nursing home. This will reduce the need for calling in extra personnel or leaving the nursing home short-handed [14, 49, 62]. In addition, the reduction in the development of confusion and delirium will release resources for other tasks at the nursing home. In addition, with mobile radiography services more treatment

will be given in the nursing home, as shown in Papers I and III. Although this may increase the types of treatment given in nursing homes, it requires nursing homes with good access to physician services, a high-quality nursing staff, and having the necessary equipment available [9, 26, 43, 47, 74]. A stronger primary care may contribute to further specialisation in the specialist health service, an overarching aim in both the WHO framework and Norwegian health policies [5, 9, 26, 43, 74]. If general treatments are moved from hospitals to nursing homes, hospitals could specialise in acute and complicated treatments and thus increase the quality of the care and treatment given in hospital [23, 46, 47, 49, 55].

To sum up this discussion on mobile radiography services' contribution to integrated, people-centred services, the evidence indicates that mobile radiography services help to coordinate health services around the nursing home residents' needs, maintain a sustainable health service, and strengthen primary care services. However, there are still only a few mobile radiography services in Norway. Societal conditions for widespread implementation of mobile radiography services in Norway will be discussed next.

## 6.3 Societal conditions for implementation of mobile radiography services in Norway

The fragmentation of health services has created administrative, funding, and informational gaps between levels of health services [9, 73]. These are related to the financial, structural, and procedural barriers for mobile radiography services identified in Paper IV. In order to develop integrated, people-centred health services, services such as mobile radiography across health service levels are needed. Thus measures should be taken within the health services in order to create a person-centred culture and an enabling environment for the implementation and use of such cross-level services [9, 11, 70]. The fifth strategy in the WHO framework – creating an enabling environment – is set to bridge the gaps found in health services which obstruct a new way of organising health services [9]. In Norway, the coordination reform describes the measures to be taken in

the Norwegian health system [5]. These conditions will be discussed in light of the utilisation of mobile radiography services, and the economic and organisational aspects of these services.

### 6.3.1 Practical issues affecting utilisation of diagnostic imaging among nursing home residents

It is evident that mobile radiography increases access to plain radiography for nursing home residents, and that this service is needed in order to provide integrated, people-centred services to these residents. However, to run mobile radiography services efficiently and coordinate treatment and care, information systems across health service levels are important [4, 9, 109]. Paper IV showed that there is a need for better electronic communication across health service levels. The lack of an electronic referral and report system between the hospital and nursing homes, and lack of technology for wireless image transfer were shown to be one of the major barriers for setting up efficient mobile radiography services.

The mobile radiography services were set up with manual routines to work around this barrier. However, manual routines are time-consuming, affecting especially the report time. Images are transferred at the end of the vehicle's round each day. Thus the images acquired in the morning may not be reported until the next day. This is especially important in rural areas where travel distance may delay reporting time even longer. With wireless image transfer, the report could, if necessary, have been given within minutes after the images were acquired as in the case of acute examinations at hospital.

For response time, the manual routines may not have the same negative effect. Paper IV showed that the nursing home staff phoned in the need for an examination and the radiographer received the referral on paper on arrival at the nursing home. However, this requires manual entry of patient information. These manual routines may increase the risk of errors in the registration and thus increase reporting time. According to Ellingsen & Monteiro [110], electronic communication forms a basis for effective integrated and

coordinated health services. This thesis indicates that further development of information technology, especially wireless image transfer from mobile services, is needed in order to spread mobile and telemedicine services to a wider user group.

### 6.3.2 Economic aspects

Demographic changes and an ageing population put pressure on the sustainability of the health services. Managers in a disease-focused health service have a tendency to maintain a narrow focus on economy and effectiveness. This has created silos in health services that work as a barrier to coordination and integration [4, 5, 9, 73]. How health services are funded therefore affects their integration and people-centredness. In order to facilitate the changes needed, financial incentives can provide effective support in both immediate and long-term change. However if the funding encourages fragmentation, the process of integrating and coordinating the health services will be demanding. Nonetheless, changing funding systems is difficult and carries a high risk of unknown effects [9, 73, 109].

The funding system of the Norwegian health services is a combined system with block grants, activity-based funding, and patient fees [27]. However, activity-based funding such as DRGs or reimbursement from NCRP-codes are based on services that are disease-focused and given within a hospital, not services delivered across health service levels [30, 111]. Consequently, this does not function as an incentive for ambulant, coordinated, or integrated services [73, 109]. This fragmented funding was shown as the main barrier for mobile radiography services in Paper IV. Due to the lack of a system for funding services across health service levels, the managers within the projects implementing mobile radiography services had difficulty funding the service. They also considered investments to be of high risk if the service only ran in the pilot period. Managers are responsible for their local budget, and because no manager has responsibility across health service levels or for keeping a societal perspective on investments and service development, benefits of services across service levels may be overlooked. For instance,

the costs of investments and running the services are visible only to the imaging department [14, 61-63] while costs for adaption of practical issues and carrying out more specialised treatments are visible in the nursing home. However nursing home managers would also see the reduction in costs for personnel accompanying residents to hospital [49, 61-63]. It is harder to take advantage of the cost reduction from fewer ambulance transfers, hospitalisations, visits to the emergency department, or family members missing work to take care of their relative. These reductions occur in departments or sectors other than where the service was set up. Thus a funding system supporting cooperation and integration is needed in order to facilitate for cross level, integrated services [109].

To facilitate integration and people-centred health services, there is a need for a mixture of financial incentives with a combination of a global payment, pay for coordination, and pay for performance funding system [4, 9, 109]. Examples of a pay for coordination incentive are (I) a capitated system where a fixed budget is set per person in need of treatment and care from both the hospital and municipality, and where both the hospital and the municipality are responsible for keeping costs within this joint budget. Or (II) pooled funds where both the hospital and municipalities contribute to a joint fund that is used for joint services [112]. According to Tsiachristas [109], a combination of global payment, pay for coordination, and pay for performance would work as a facilitator for coordination and integration of services. There are both positive and negative effects of all type of financial incentives, nonetheless Tsiachristas [109] emphasises that such a combination would stimulate new implementations, more efficient administrative systems, quality improvement, and would secure different patient groups a good service [109]. However, to succeed in changing health services using these financial incentives, other aspects of the health service need to be in place. According to Tsiachristas [109] there is a need to know the population and its needs, have measurable goals for the health services, and have relevant quality indicators. Furthermore, there is a need for openness and a willingness to report outcomes, have shared goals across levels and sectors, have a strong primary care-based system, have a long-term perspective on results from changes, and integrated information systems [109, 110]. Today the

Norwegian health services do not satisfy all these aspects and there may be a need to change both economic incentives and to develop shared goals, integrate information systems, and strengthen primary care, for example.

Through the coordination reform, funding of coordinated services was to be handled through the use of contracts between municipalities and hospital [5]. As shown in Paper IV, managers from different organisations, one hospital and up to ten municipalities met to set up a contract for implementing mobile radiography services. The contract system developed through the coordination reform was intended to secure cooperation, quality development, and task allocation between the health service levels [5]. As shown in Paper IV, the use of contracts was seen as both a barrier to and a facilitator of mobile radiography services. The contracts facilitated most of the projects since there was a lack of alternative ways to secure funding of the service beyond the pilot stage. However, the process of setting up contracts and maintaining these was seen as a bureaucratic and time-consuming process, especially where many parties were involved. In one of the implementation projects, the use of contracts was discarded, as not worth the troublesome process, and the hospital funded the service alone. This made it possible to set up the service quickly and the process was considered less bureaucratic, both in implementation and when running the service. This was because contracts did not need to be set up, renegotiated, and kept up to date. Furthermore, adding more municipalises at a later time is often complicated. And extending the area was described as troublesome. Nevertheless the original municipalities cooperated closely with the hospital and they set up a service tailored to their area, thus changing the dynamics in the group. Shared goals and values were shown as success criteria in this process [113]. Paper IV showed that the individuals involved in the process of setting up contracts were seen as the main facilitators. They met each other as equals, with the joint aim of setting up a service in the best interests of the nursing home residents. In a different collaborative environment they may not have succeeded.

In addition to the use of contracts in the implementation of the coordination reform, a fund was set up where municipalities could apply for funding for coordinated projects together with a hospital [114]. This fund was temporary, and contributed to the implementation of a few mobile radiography services. However, the funding of further operating mobile radiography services as discussed earlier was not facilitated by reimbursement from the NCRP system. Nonetheless, in 2018 a separate code for ambulant radiological examinations was introduced in the NCRP system [115], adding € 10 per visit to the normal reimbursement of plain radiography (€ 1.7). One visit includes all examinations made of one resident at the same time. Thus one examination could include more than one modality-specific NCRP code [115]. However, doing a plain radiography examination in hospital was calculated to have a cost of € 100 in Paper III, whereas an examination at the nursing home was calculated to have a cost of € 144 per examination, constituting a cost difference of more than €40 for the imaging department. The € 10 additional reimbursement, may be seen as an acknowledgment of the effectiveness of mobile radiography services and intended to support the existing services. However, there seems to be a need for a coordination incentive in order to facilitate the widespread availability of mobile radiography services in the Norwegian health services. The establishment of such incentives would facilitate other cross level or telemedicine services as well.

### 6.3.3 Organisational aspects

The funding system in the health services has a huge influence on how services are developed, managed, and run [9, 109]. In Paper IV, the financial barriers were found to be related to the structural barriers. The managers described difficulties in getting top-management support and thus funding in all organisations involved in the projects. Most of the managers in these fragmented services did not see the societal perspective, focusing on their local budget and conditions. Mobile radiography services and other services working in between levels of the health service may suffer from not really being anyone's responsibility [71, 73].

Collaborative leadership, bringing together different stakeholders, and changing management strategies are assumed to be needed in order to take the health services through the complex changes needed to create integrated, people-centred health services [9, 73, 102]. In fragmented services, such as the Norwegian health services today, the lack of such collaboration has created administrative gaps [5, 9, 73]. As shown in Paper IV, a network of managers was a success criteria in implementing an across level service. Managers from imaging departments and municipalities met for the first time in the mobile radiography service implementation project. There was very little communication and coordination between them beforehand. Paper IV showed that managers from different levels shared a common goal and met each other with respect and understanding. This relationship built a new network of connections between primary and specialist health services. Paper IV showed that this network was important for planning the service and setting up collaboration routines.

In creating an enabling environment for people-centred services, it is important for all healthcare personnel to engage and contribute to the changes in health service delivery [5, 9]. Paper IV showed that the knowledge of needs, possibilities and challenges in respect of the residents, staff and organisations was sparse across levels. Thus problems arose when not all parties were involved in the planning of the service and when setting up routines. Further, Paper IV showed that a network between the imaging department staff and the nursing home was needed in order to succeed in the implementation. The use of such networks is necessary on all levels in the participating organisations [113]. All physicians and nurses working in nursing homes required information about the existence of this new service, the purpose of the service, and how to use it. The radiographers needed to familiarise themselves with the routines of the nursing homes. Nurses, nurse assistants, and radiographers also needed to create and learn the procedures for an X-ray examination at a nursing home. This took time and cooperation across levels, and managers needed to allocate time for this work.

In order to be able to support transformational changes, the WHO framework emphasises that evaluation of the implementation, sharing experience and knowledge,

and using this knowledge in decision-making on all levels of health services are important [9]. In addition, according to Greenhalgh et al. [113], the ability to evaluate and change the service in line with issues occurring in an implementation process is a criterion for successfully implementing innovations in organisations. Paper IV showed that managers in the mobile radiography service projects used continuous evaluations in the coordination meetings during the implementation project. It was considered useful in order to track use of the new service, give feedback on quality, the cooperation environment, and to encourage the different municipalities to use the service. Thus evaluations seem to be a tool familiar to the managers, and they facilitated the implementation.

To enable an integrated, people-centred health service, WHO emphasises the importance of sharing knowledge [9]. Managers interviewed in this project emphasised the failure to disseminate knowledge of mobile radiography services through research or reports from implementation processes. Moreover, this lack of shared knowledge and experience was a barrier in the process of negotiation for funding and planning the service. It seemed vital, therefore, that implementation projects report their knowledge and experience publicly or include research in their implementation projects that can be published. However, in most of the mobile radiography projects, knowledge and experiences were merely reported in internal reports to local management. In consequence, there seems to be a potential for increased knowledge sharing in the Norwegian health services.

To sum up this discussion on societal conditions, this thesis has shown that the funding and organisation of today's fragmented health services obstruct integration and development of coordinated health services. In the following chapter, conclusions and recommendations for facilitating integrated and people-centred health services through telemedicine will be given as well as recommendations for further research.

# 7 Conclusions, recommendations and further research

Through an examination of the utilisation of mobile radiography services in nursing homes and the economic and organisational aspects of these services, this thesis has demonstrated three areas where mobile radiography services could contribute to integrated, people-centre health services for nursing home residents.

I) Mobile radiography services contribute to **increased access to imaging services**, providing more accurate diagnosis and thus better treatment and care for nursing home residents, tailored to their need for a familiar environment and coordinated services. The reduction in transfers to hospital and hospitalisations caused by mobile radiography services helps to keep residents within their familiar environment. This reduces negative consequences for residents and further enables nursing homes to provide holistic and coordinated treatment and care. However, mobile radiography services reduce the use of CT and ultrasound. Thus mobile radiography may reduce diagnostic accuracy for some residents. This may point to a need for mobile CT and ultrasound services.

II) Mobile radiography services contribute to the **strengthening of primary care**. Giving more treatment in the nursing home allows the transfer of tasks from hospitals to primary care, thus contributing to increased diversity and complexity in treatments given in nursing homes. In order to be able to give high quality care, increased knowledge and investment in more specialised equipment may be required in nursing homes.

III) Mobile radiography services contribute to a better **utilisation of the health service resources**. With a 30% cost reduction per examination and treatment, society's resources would be used more efficiently in nursing homes, prehospital, and hospital services. However, there are barriers within the health services for large scale implementation of mobile radiography services. These barriers are present in the management and funding of the health services, and in information technology systems. Based on these findings, recommendations for facilitating integrated, people-centred health services have been developed and will be presented next.

## 7.1 Recommendations for further facilitating integrated, people-centred health services for nursing home residents

This thesis identifies significant barriers within the Norwegian health system to integrated, people-centred health services to the nursing home population. Based on these findings, three aspects of the Norwegian health system should be evaluated and changes considered. These aspects are presented in Figure 6.

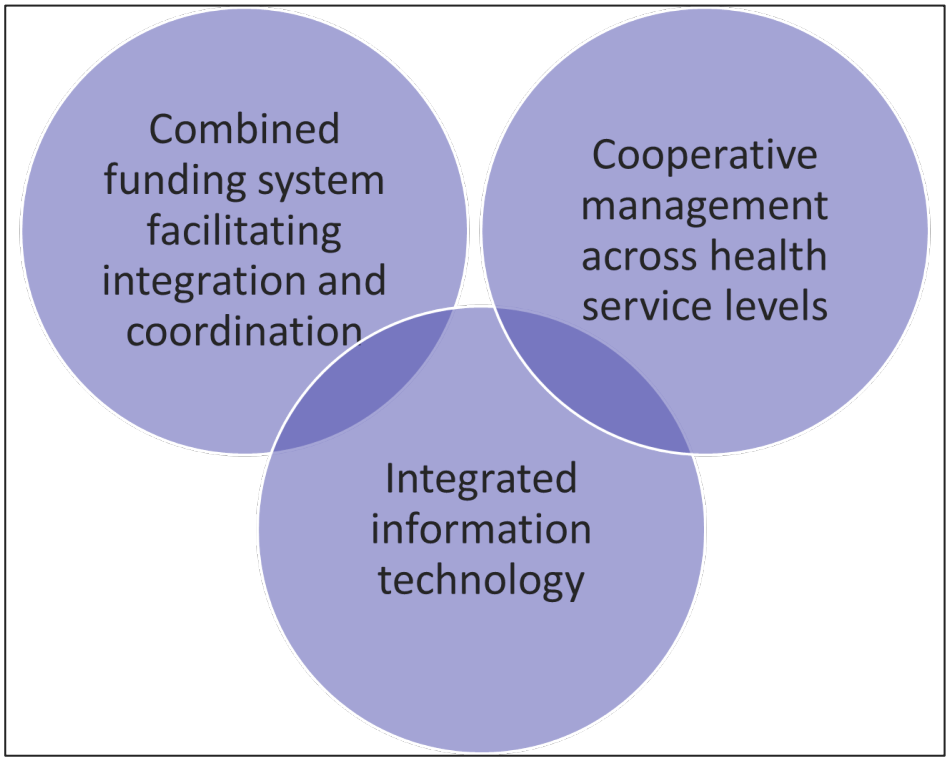



*Figure 6: Aspects to consider changing in order to facilitate a more integrated, people-centred health service for nursing home residents.*

The first aspect is the funding of the health services. In order to incentivise integrated, people-centred health services, a combined funding system is recommended [9, 73, 109]. For the implementation of mobile radiography, the barrier of the lack of pay for coordination incentives became evident. The imaging department mostly considered mobile radiography services impossible for them to fund, since it would be too costly. This points the well-known problem of financial incentives. Financial incentives focus care delivery to the types of treatments or examinations that are refundable, and health

organisations strive to perform these as simply and cheaply as possible within their local budget [73, 109].

The second aspect where change is recommended is within management. Collaborative management on all levels of the health services should be set up in order to bring different stakeholders together, and there is a need for networking across health service levels and sectors [9, 73]. In mobile radiography the development of the service and cooperation in a network of managers with a common goal constituted a key component for success in changing the imaging service. This would be transferable to other services as well, and coordination projects could emerge from managers meeting across health service levels and across sectors to discuss common goals for the health services [4, 9, 73].

The final recommendation relates to information technology. In order to integrate and coordinate services across health service levels and long distances, information technology is an essential tool [9, 13, 37, 110, 116]. In the Norwegian health services today, the information system is fragmented, and different information systems are used in different organisations and departments. Thus information about the patient is not available across organisations or health service levels [116]. The National Strategy for eHealth [116] focuses on a joint medical record system in Norway accessible for individuals and across health organisations and levels. However, this does not include image transfer. Not being able to transfer images constitutes a major barrier for mobile radiography services and as well as for mobilising other modalities. Thus a strategy facilitating coordinated telemedicine technology in the Norwegian health services should be developed in order to utilise the potential of telemedicine for integration and people-centred health services.

## 7.2 Further research

In relation to mobile radiography services in nursing homes, this thesis does not explore all domains of MAST. There is still a lack of knowledge from the patient perspective, the

radiographers' perspective, and socio-cultural, ethical and legal domains. In addition, there is a need for more knowledge on the effects of mobile radiography services on nursing home residents' quality of life, in order to be able to perform cost-effectiveness or cost-benefit analysis.

Further, the findings in this thesis highlight the need for further research into the utilisation and mobilisation of other imaging modalities and other settings, using the MAST framework.

- Assessment of the use of CT ambulances in nursing homes.
- Assessment of mobile ultrasound services.
- Assessment of a combined mobile radiography and ultrasound service.
- Assessment of mobile radiography services in prisons, sheltered housing, and people's homes.
- Assessment of rural mobile radiography services.
- Assessment of mobile radiography in other countries.

Such assessments as those listed above could lead to a wider use of mobile services in diagnostic imaging, and contribute to a more integrated, people-centred health service for nursing home residents, and other vulnerable or isolated groups of the population.

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# Paper I

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# Mobile radiography services in nursing homes: a systematic review of residents' and societal outcomes

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## Abstract

**Background:** Demographic changes are leading to an ageing population in Europe, and predict an increase in the number of nursing home residents over the next 30 years. Nursing home residents need specialised healthcare services such as radiology due to both chronic and acute illnesses. Mobile radiography, x-ray examinations performed in the nursing homes, may be a good way of providing services to this population. The aim of this systematic review was to identify the outcomes of mobile radiography services for nursing home residents and society.

**Methods:** A systematic review based on searches in the Medline, Cochrane, PubMed, Embase and Svemed + databases was performed. Titles and abstracts were screened according to a predefined set of inclusion criteria: empirical studies in the geriatric population, and reports of mobile radiography services in a clinical setting. All publications were quality appraised using MMAT or CASP appraisal tools. Data were extracted using a summary table and results were narratively synthesised.

**Results:** Ten publications were included. Three overarching outcomes were identified: 1) reduced number of hospitalisations and outpatient examinations or treatments, 2) reduced number of transfers between nursing homes and hospitals and 3) increased access to x-ray examinations. These outcomes were interlinked with the more specific outcomes for residents and society reported in the literature. For residents there was a reduction in burdensome transfers and waiting time and adequate treatment and care increased. For society, released resources could be used more efficiently, and overall costs were reduced substantially.

**Conclusions:** This review indicates that mobile radiography services for nursing home residents in the western world are of comparable quality to hospital-based examinations and have clear potential benefits. Mobile radiography reduced transfers to and from hospital, increased the number of examinations carried out and facilitated timely diagnosis and access to treatments. Further research is needed to formally evaluate potential improvements in care quality and cost-effectiveness.

**Keywords:** Mobile radiography service, Nursing homes, Socio-economics, X-ray, Telemedicine

## Background

Increased interest in demographic changes in our society leading to an ageing population highlights the need for healthcare services to be more effective maintaining high quality standards [1]. An increase in the number of persons living in nursing homes is expected over the next 30 years [1]. Today, nursing home residents are living with several chronic illnesses and up to 80% have dementia [2–4]. In addition, there is a high incidence of acute illnesses such as infections, cardiovascular incidents and injury due to falls [3, 4]. Both chronic illnesses and acute illnesses increase the need for specialist healthcare services for these residents compared to the rest of the population [3]. According to Graverholt and Riise [4] almost 45% of admissions to hospital from nursing homes are related to falls, respiratory infections and diseases of the digestive system [4]. For these indications, conventional x-ray examinations such as chest,

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musculoskeletal and abdominal images are important diagnostic tests [5, 6]. Today, nursing home residents often require transfer to a hospital or an emergency room (ER) to attend radiological services. The sudden change in environment for the nursing home residents, and especially persons suffering from dementia, can affect the person's orientation and sense of security. Transportation and new surroundings such as the x-ray department in a hospital may lead to increased anxiety or disorientation [7]. Inadvertently transfer to hospital may do more harm than good for a nursing home resident, thus hospitalisation should be avoided [2, 5]. In addition, the transfer may affect cost and acceptability of radiological services [8].

It is possible to perform conventional x-ray examinations in nursing homes as a telemedicine service [8, 9]. Mobile radiography services use small, lightweight, portable x-ray equipment with a digital detector [8]. The radiographer drives a vehicle equipped with a wheelchair ramp carrying the equipment and performs the examination with assistance from the nursing home staff in the resident's room [8]. The images can be quality assessed on site and transferred to the radiology department for interpretation [8]. Image quality of examinations in nursing homes is adequate for making a diagnostic decision [10]. Mobile radiography services have been set up in a few countries, for instance in Australia, Canada, Norway, Sweden and the USA [8, 11–14]. However, further knowledge is needed about the outcomes of mobile radiography services for nursing homes residents.

The aim of this systematic review was to identify the outcomes of mobile radiography services for nursing home residents and for society in general.

## Methods

To the authors' knowledge, this is the first systematic review aiming to identify outcomes of mobile radiography services for residents and society.

### Eligibility criteria

Empirical studies of mobile radiography services in a clinical setting for geriatric nursing home study populations were considered. The focus was on higher-level outcomes of diagnostic imaging on the levels "therapeutic", "patient outcome" and "societal" efficacy, as described by Fryback and Thornbury [15]. In this review, the following designs were eligible: randomised controlled trials, non-randomised trials, descriptive studies, mixed-methods studies, socio-economic evaluations and qualitative studies.

### Literature search

The following databases were searched: MEDLINE Ovid, Cochrane Library, PubMed, Embase Ovid and Svemed+. The search strategy was developed in MEDLINE (Ovid) (Table 1), and was further adapted for the other databases. The terms used were derived from two categories: the population (nursing home resident) and intervention (mobile/portable radiography service OR mobile/portable x-ray service). The complete search strategy used is available in (Additional file 1: Table S1). The literature searches were carried out from December 2015 to February 2016, the last search on February 5$^{th}$ 2016.

No language filters or date restrictions were used in the searches. The search was expanded by snowballing techniques screening for citations of the selected studies (Google scholar), reference lists and conference programmes. Grey literature like socio-economic evaluations were searched for using Google. The keywords used in Google are available in (Additional file 1: Table S2).

### Selection of records and methodological quality appraisal

The records were archived using Thomson Reuters EndNote X7.4 library and duplicates were removed. All titles and abstracts were screened by EK for eligibility, and a 10% sample was double-checked by KBL.

Mixed Methods Appraisal Tool (MMAT) was used for appraisal of the methodical quality of all studies, except economic evaluations. MMAT is considered appropriate for appraisal of qualitative, quantitative as well as mixed methods studies [16]. The Critical Appraisal Skills Program (CASP) tool [17] was used to appraise the methodological quality of the economic evaluation studies. EK and KBL read all the publications selected for full-text screening, appraised them, and agreed on the final grades and inclusion through discussions.

**Table 1** Search strategy in MEDLINE (Ovid)

| # | MEDLINE Ovid |
|---|---|
| 1 | nursing homes/or intermediate care facilities/or skilled nursing facilities/ |
| 2 | Homes for the Aged/ |
| 3 | (nursing adj (home* or facilit*)).tw. |
| 4 | (home? for the aged or home? for the elderly).tw. |
| 5 | ((intermediate or long-term or longterm) adj care facilit*).tw. |
| 6 | 2 or 3 or 4 or 5 |
| 7 | exp Diagnostic Imaging/ |
| 8 | ((diagnostic or medical) adj (radio* or x-ray* or x ray*)).tw. |
| 9 | exp Radiography/ |
| 10 | (mobile adj (radio* or x-ray* or x ray*)).tw. |
| 11 | (portable adj (radio* or x-ray* or x ray*)).tw. |
| 12 | exp Telemedicine/ |
| 13 | (telemedicine adj (radio* or x-ray* or x ray*)).tw. |
| 14 | 7 or 8 or 9 or 10 or 11 or 12 or 13 |
| 15 | 6 and 14 |

### Data extraction and synthesis

Data were extracted using a summary table based on recommendations by Støren [18]. The summary table was composed of the following categories: author, title and year, background, objective, research question, keywords, design, population, methods, results, conclusion, further questions, clinical implications and limitations. EK extracted data from all publications and KBL from 30% of the publications for quality assurance purposes.

A narrative synthesis was chosen due to the variety of methodologies used in the studies included in this review. This narrative synthesis included a familiarisation process of the results, methodological appraisal and transformation of quantitative data. Further, description and tabulation of data and performing a content analysis, and finally the authors discussed the synthesis through critical reflection until agreement was achieved [19].

## Results

Database searches, Google searches and snowballing identified 2548 individual records, which was reduced to 2238 after duplicates were removed. Two thousand two hundred twenty one excluded publications did not report on mobile radiography services. After screening, 17 full text publications were appraised.

Seven publications were excluded because of overlapping publications (from the same study), non-clinical settings, non-empirical designs or being technical or diagnostic accuracy efficacy assessments. An overview of excluded articles is available in Additional file 1: Table S3. No publications were excluded because of language. Figure 1 shows the selection process in detail.

Ten publications were included in this review: eight articles, one conference abstract, and one socio-economic evaluation.

### Characteristics of the included publications

Among the included publications are; one randomised controlled trial (RCT), one qualitative focus group interview study and three socio-economic analysis. The rest of the included publications reported on outcome of mobile radiography services based on different quantitative descriptive methods. Publications in English, Norwegian and German were included in the review. Further characteristics of the publications are listed in Table 2, along with scores for methodological quality. The detailed assessment of methodological quality, in MMAT or CASP forms, for each publication are available in (Additional file 1: Tables S4 and S5 respectively).

In the analysis, it was found that the outcomes were on different levels and highly interlinked. Some outcomes were overarching in the sense that they are likely to influence or can explain other outcomes. Overarching outcomes of mobile radiography services are presented

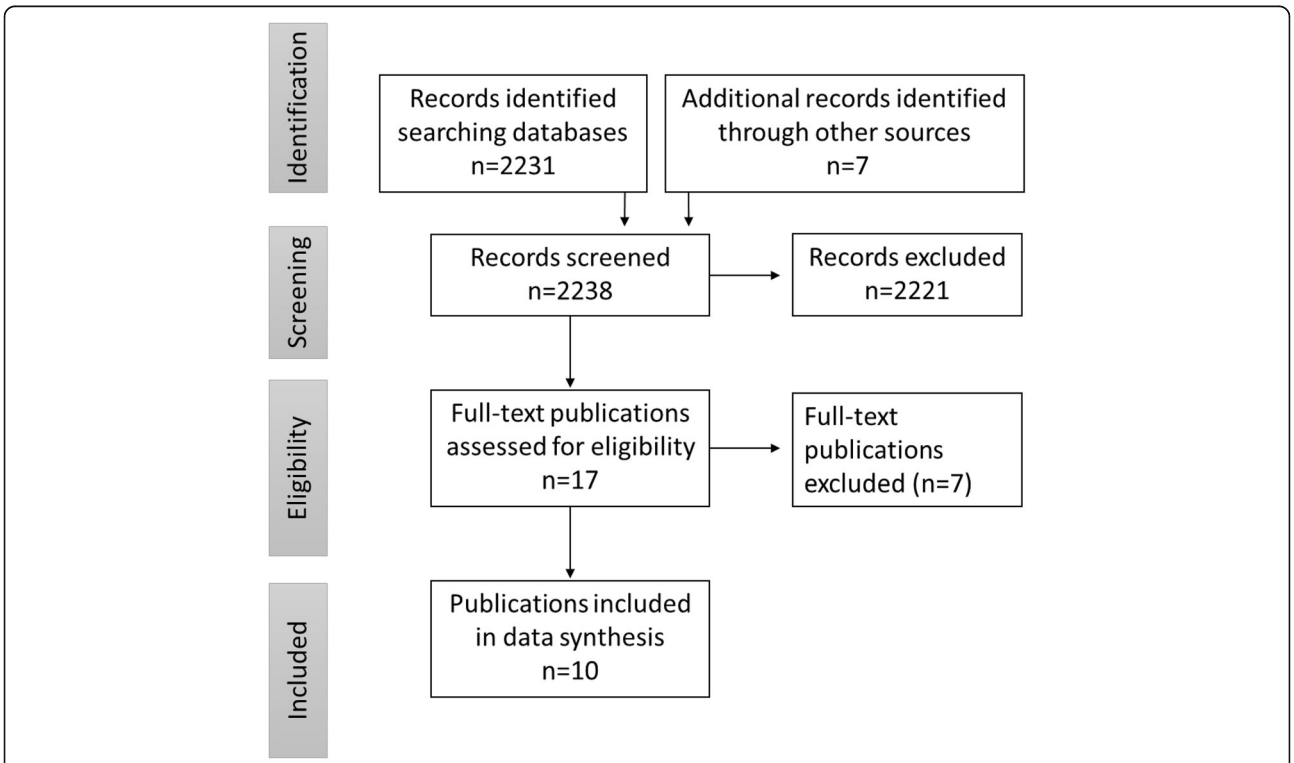


**Fig. 1** Flowchart of the selection process

**Table 2** Characteristics and methodological quality score of the publications included in the review

| Author and year | Aim/objective | Design | Methods | Scope and type of data | Respondents | Area and nationality | MMAT/ CASP grade[a] |
|---|---|---|---|---|---|---|---|
| Eklund 2011 [25] | Investigate the usefulness of a mobile radiography service for radiological assessment of patients in nursing homes from the patient and staff perspectives | Prospective, descriptive, quantitative study | • Questionnaire for nurses and residents<br>• Registration form for image quality<br>Telephone survey of outcome and treatment | 123 nursing homes residents | Registered nurses at 25 nursing homes 62 residents | Lund, Sweden | **** |
| Forat Sadry 2010 [22] | Investigate satisfaction with mobile services among referring physicians and nursing home staff | Prospective, descriptive, quantitative study | Questionnaire | 318 nursing home residents using the mobile radiography service in 2007 | Referring physicians and nursing home staff | BaselStadt, Baselland and Genf, Switzerland | * |
| Lærum 2005 [23] | Consequences for residents transferred to hospital for examination and treatment | Prospective, descriptive assessment | Questionnaire | 714 nursing home residents | Nursing home staff at six nursing homes | Oslo, Norway | **** |
| Lærum, Sager, Oswold 2005 [20] | Investigate feasibility of mobile services for residents, referring physicians and the nursing homes compared to outpatient services | Prospective, descriptive, quantitative study | Questionnaire | 197 nursing home residents | Nursing home staff at 31 nursing homes | Oslo, Norway | *** |
| Montalto 2015 [21] | Measure the impact of the mobile x-ray service on emergency department attendances by residents of residential aged care facilities who require plain X-ray services | Retrospective before-and-after cohort | Registry data analysis | Residents of 30 nursing homes frequently using the mobile x-ray service | n/a | Melbourne, Australia | **** |
| Richauda 2011 [27] | Explore the quality of imaging and clinical outcomes of using mobile, light-weight x-ray equipment to provide radiologic examinations to frail elderly patients at home | Randomized controlled trail (RCT) | a) Confusion Assessment Method<br>b) Delirium Rating Scale European Guidelines on Quality Criteria | 69 immobilized or chair bound patients, acutely ill at intermediate or high risk of delirium in need of a radiological examination | 7 radiologists | Torino, Italy | **** |
| Thingnes & Stalsberg 2010 [26] | Explore aspects that nurses, nurse assistants and radiographers perceive important when implementing mobile radiography services to nursing homes | Qualitative | Focus group interviews | Health care personnel from one nursing home and one hospital | Radiographers, nurses and nurse assistants | Norway | *** |
| Dozet 2015 [29] (abstract) | The aim of this study was to investigate whether mobile radiography was more cost-effective from a societal perspective, compared to hospital based radiological examinations. | Cost-effectiveness analysis | Prospective cost-minimization analysis | X-ray examinations in nursing homes (315 residents) compared to outpatient examinations (77 residents) | n/a | Lund, Sweden | * |
| Price Waterhouse Coopers 2006 [28] | Socio-economic cost-benefit analysis of shifting to mobile radiological services | Socio-economic cost-benefit evaluation | Literature review, interviews and valuing monetized effects | Registry data, reports and pilot project | Key personnel | Seven cities or areas of Norway | **** |
| Randers 2005 [24] | Estimate socio-economic costs comparing two different ways of performing x-ray examinations of nursing home residents | Socio-economic cost evaluation | Costs analysis | Resources used and related cost statistics for mobile and stationary services | n/a | Norway | *** |

[a]In MMAT, papers are graded from 25% (one criteria met = *) to 100% (all criteria met = ****) [16]. In the CASP economic evaluation checklist, section B "How were costs and consequences assessed and compared?" publications were graded from 25% (1–2 criteria met = *) to 100% (all criteria met = ****)

separately. Figure 2 shows an overview of the main findings and indicates how they may be interrelated.

### Overarching outcomes of mobile radiography services

First, mobile radiography services reduced the amount of hospitalisations, outpatients treatment and examinations in hospital or ER. Examination in the nursing home facilitated for instance, treatment of pneumonia in the nursing home instead of at the hospital or ER [5, 11, 20, 21]. Laerum and Sager [20] reported a 6% reduction in hospitalisation of nursing home residents after introducing mobile radiography services in Oslo. According to Montalto, Shay [21], nursing home residents' presentation at the ER decreased by 11.5% the first year after introducing mobile radiography services in Melbourne.

Second, mobile radiography services reduced the use of ambulance and taxi transportation of nursing home residents for treatment or examination in hospitals or ERs. Two studies reported a 90–94% reduction in transfer of residents for outpatient x-ray examinations after introduction of mobile services [20, 22]. If the mobile radiography services had not been available, 50–88% of residents would have needed ambulance transportation and the rest would have needed a wheelchair taxi, regular taxi or private car [20, 22, 23].

One study reported on staff needed to accompany residents in transfer, and found that 75% of the residents needed nursing home staff to accompany them in transfer and while waiting [23]. Further, the next of kin accompanied 25% of the residents, and a few residents were accompanied by both staff and next of kin [23]. In addition, mobile radiography services reduced the time spent per examination. Randers [24] estimated a total of approximately 25 min per examination in a nursing home (from the arrival of the vehicle to departure). Two studies reported residents to be away for 4–5 h on average when going to an outpatient clinic in an urban area [23, 25]. According to Eklund, Klefsgård [25] and Thingnes and Stalsberg [26] most of this time was spent waiting or in transfer.

Finally, the number of necessary examinations performed increased when mobile radiography services were introduced. Laerum, Sager [20] reported 10% of the residents in their study were not able to be transferred for an outpatient examination. Further, residents often refuse to be transferred to hospital because they are scared according to Thingnes and Stalsberg [26]. Thus, mobile radiography services provided access to a radiological service for these residents and increased the number of residents receiving diagnostic services.

### Outcome for nursing home residents

There were two main outcomes for nursing home residents: First, avoiding hospitalisation, outpatient examination/treatment and transfer reduced the negative consequences for nursing home residents [23, 26, 27]. Second, radiological tests facilitated more adequate treatment and care [20, 25, 27].

Three studies reported the negative potential consequences for residents. According to Laerum, Åmdal [23] outpatient examinations were responsible for exhaustion and in certain cases confounded with confusion in 45% of the residents in their study [23]. Ricauda, Tibaldi [27] found that 17% of residents examined at the hospital developed delirium within a few hours after the examination. X-ray examination at the nursing home had an insignificant impact on residents [23] and none developed delirium [27]. In the qualitative study, the nurses and nurse assistants described residents to be confused, scared, restless and in pain when examined at the hospital.

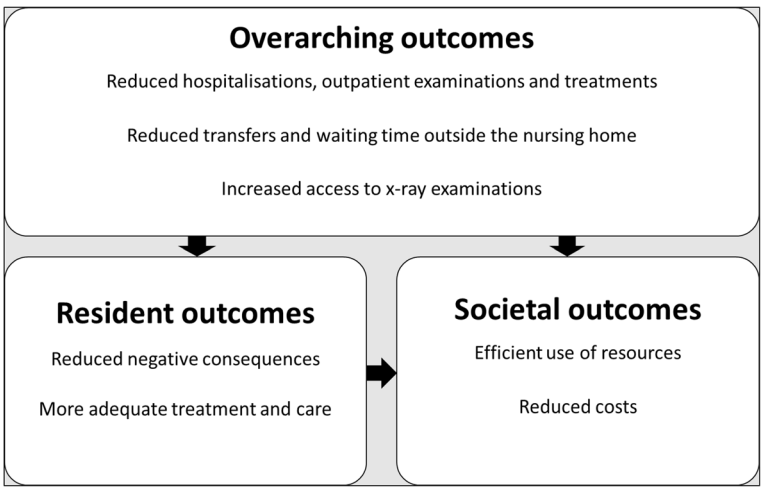


**Fig. 2** Outcomes of mobile radiography services. The arrows indicate links between overarching, residents' and societal outcomes

Furthermore, nursing home residents can cause disturbance for other patients at the radiology department [26].

Laerum, Åmdal [23] reported that the negative consequences for residents increased with the amount of time spent away from the nursing home. More than two and a half hours gave a significant ($p < 0.001$) increase in negative consequences for residents [23]. As previously described, residents are on average 4–5 h at the hospital for an outpatient x-ray examination [23, 25].

X-ray examinations provided important information for the treatment and care of nursing home residents. Three studies described the therapeutic outcome of examinations. For 58–70% of the examinations, the assumed diagnosis was confirmed and for 40% the tentative diagnosis was disproven [20, 27]. This was similar to examinations performed in a hospital [27]. According to Eklund, Klefsgård [25], 29% of the examinations in their study demonstrated significant pathology. Laerum, Sager [20] described that the findings of the mobile examinations had consequences for the medical treatment for 85% of the residents, and for care plans for 71% of the residents [20]. Hence, mobile services improved the adequacy of the treatment and care of nursing home residents.

### Societal outcomes

To invest in a vehicle and new equipment in addition to reorganising the way the radiographers work may have led to an increase in costs [24, 28]. However, the reduction in hospitalisations, transfers, staff accompanying residents and hospital/ER treatment reduced costs in both hospitals and nursing homes, thus for society as a whole [24, 28, 29].

When up to 75% of residents needed to be accompanied by healthcare staff and they were away on average 4–5 h [23, 25] the absence of staff have negative potential consequences for the other residents at the nursing home and the remaining nursing home staff, because the home is left short-handed [23, 26]. However, additional staff may be called in, which led to an additional increase in costs [28]. For society, 25% of the residents needed their next of kin to accompany them; this may have reduced effectiveness in the rest of society when employees have to take the day off work to take care of their family member [23].

Three publications from local projects in Norway and Sweden compared the cost of mobile radiography services with the cost of outpatient examinations, resulting in 30–60% cost reduction per examination. The size of the reduction depended on the distance between the nursing home and the hospital, in addition to the number of residents examined per visit [24, 28, 29].

## Discussion

The purpose of this systematic review was to create a better understanding of the outcomes of mobile radiography services compared to conventional x-ray examinations. Ten publications were included.

### Outcome of mobile radiography services

This review indicates three overarching outcomes of the introduction of mobile radiography services: a reduction in transfers from nursing homes to hospital or the ER for examination, treatment or care, a reduction in burdensome waiting time in hospital, and increased access to radiological procedures.

These overarching outcomes reduced the negative potential consequences for nursing home residents in need of x-ray examinations, and improved access to radiological tests for residents who for various reasons were unable to be transferred [20]. Furthermore, an x-ray examination facilitated more appropriate treatment and care [20, 24, 27]. This was of course dependent on the image quality being adequate for diagnosing. Studies comparing image quality in examinations carried out in hospitals and in nursing homes reported adequate diagnostic quality regardless of where the examination took place [10, 25, 27]. When examined at the nursing home, more residents would also be treated locally [20, 21]. This may have led to greater responsibilities for the nursing home staff, which may influence decisions about whether to send resident for acute treatment or examination at a hospital or to wait for the radiography services [26]. Conversely, treatment given locally facilitated coordination and continuity of treatment and care, which is important for this fragile population [23, 30].

For society, this review indicates that mobile radiography services could reduce healthcare costs by using resources more efficiently [24, 28, 29]. Both reduction in transfers with accompanying staff and changes in where treatment were given contributed to a cost reduction of 30–60% per examination [21, 24, 26, 28, 29]. Family members who accompanied residents to hospital, may be absent from work for one whole day. This would generate negative economic impact at a societal level.

Population demographics in the western world are changing with increasing life expectancy and fewer births. Ageing populations with increased healthcare needs and thus, increase in costs coupled with constrained resources creates efficiency pressures on healthcare services [31–33]. The European Commission calls for the use of telemedicine, new technology and a personalised healthcare system to meet these challenges [8, 33]. This review suggests that mobile radiography services can provide an effective alternative to outpatient x-ray examination for nursing home residents [24, 28, 29], in addition this can contribute to meet the challenges for healthcare efficiency. To date, only a few countries have introduced mobile radiography services. Barriers within the healthcare systems may prevent the establishment of these kind

of services. Generally, in Europe telemedicine services are limited to local small-scale projects [9]. Hence, these barriers may be common for services that are organised differently than "ordinary" healthcare services. The way telemedicine services are organised may not fit the system of reimbursement from the health authorities. This may cause co-payment to be applied, which in turn may affect service provision or use [9]. Another reason may be lack of knowledge among decision-makers working in healthcare of the beneficial outcomes of mobile radiography services.

### Strengths and limitations

The search in the databases was systematic, and no language or date restrictions were used, thus the search strategy was exhaustive and it is likely to have been complete. The term mobile radiography services is also used to describe mobile radiography services within a hospital intensive care unit or at the emergency department. However, this did not cause any irrelevant hits because mobile/portable radiography/x-ray was combined with various terms for nursing home/home for the aged etc. Still, there were few studies and evidence was scarce. The variety in quality of the included publications limited the strength of the conclusions made in this review. The quality of evidence in systematic reviews are reflected in the level of confidence in the findings in the included studies [34]. The included publications were mostly related to programmes for introducing mobile radiography services in a community, which may have led to a bias towards positive outcomes of these services. However, with limited studies published it is important to identify existing knowledge in order to facilitate further research. Thus, publications were included despite suboptimal quality grading. Further, the types of studies included makes a narrative synthesis of results to be the best solution.

Notwithstanding its limitations, this review identified important benefits for nursing home residents and for society. Healthcare policies call for changes in organisation and efficiency, in addition to the use of new technology and telemedicine to reduce the strain on specialist healthcare [1, 9, 33, 35, 36]. Further research is needed to evaluate the outcome of these services in larger scale studies from different geographical areas (urban and rural). In addition, the outcome for individual residents and next of kin should be studied in more depth. The latter is presently unknown. There is a need for robust cost-effectiveness analyses from larger areas and more countries. Further, research is also needed to examine potential barriers to the implementation of telemedicine services in healthcare systems [9].

## Conclusion

This review indicates that mobile radiography services for nursing home residents in the western world are of comparable quality to hospital-based examinations and have clear potential benefits. Mobile radiography reduced transfers to and from hospital, increased the number of examinations carried out and facilitated timely diagnosis and access to treatments. Reduction in transfers, waiting times and exposure to unfamiliar environments contributed to the psychosocial well-being of nursing home residents and reduced disruption for carers and families of residents. Further research is needed to formally evaluate potential improvements in care quality and cost-effectiveness.

## Additional file

**Additional file 1:** Includes a complete search strategy, reasons for excluded articles and the MMAT and CASP checklists for all included articles. **Table S1.** Search strategy. **Table S2.** Searches in Google and Google Scholar. **Table S3.** Excluded articles with reasons. **Table S4.** Mixed Methods Appraisal Tool (MMAT) assessment of included studies. **Table S5.** CASP appraisal of economic evaluations included in the review. (DOCX 60 kb)

#### Abbreviations

CASP: Critical Appraisal Skills Program; ER: Emergency room; MMAT: Mixed Methods appraisal tool; RCT: Randomized controlled trial

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#### Availability of data and materials

The complete search strategy is available in Additional file 1: Tables S1-S2. The data sets supporting the conclusion of this article are included within the article and its additional file.

#### Authors' contributions

Both EK and KBL contributed to the conception of the study and to the development of the protocol of this review. EK performed the searches, did most of the screening and drafted the manuscript. Both authors took part in the interpretation of the data, revision and approval of the final manuscript.

#### Competing interest

The authors declare that they have no competing interests.

#### Consent for publication

Not applicable.

#### Ethics approval and consent to participate

Not applicable.

## Publisher's Note



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**Contents - Additional file**



## Table A1: Search strategy

| | Cochrane Library 18.01.2016 | |
|---|---|---|
| **ID** | **Search** | **Hits** |
| #1 | MeSH descriptor: [Nursing Homes] explode all trees | 1067 |
| #2 | MeSH descriptor: [Homes for the Aged] explode all trees | 505 |
| #3 | (nursing next (home* or facilit*)):ti,ab,kw | 2327 |
| #4 | ("home? for the aged" or "home? for the elderly"):ti,ab,kw | 545 |
| #5 | ((Intermediate or long-term or longterm) next care facilit*):ti,ab,kw | 482 |
| #6 | #1 or #2 or #3 or #4 or #5 | 2729 |
| #7 | MeSH descriptor: [Diagnostic Imaging] explode all trees | 32141 |
| #8 | ((diagnostic or medical) next (radio* or x-ray* or x ray*)):ti,ab,kw | 55 |
| #9 | MeSH descriptor: [Radiography] explode all trees | 14110 |
| #10 | (mobile next (radio* or x-ray* or x ray*)):ti,ab,kw | 11 |
| #11 | (portable next (radio* or x-ray* or x ray*)):ti,ab,kw | 3 |
| #12 | MeSH descriptor: [Telemedicine] explode all trees | 1374 |
| #13 | (telemedicine next (radio* or x-ray* or x ray*)):ti,ab,kw | 1 |
| #14 | #7 or #8 or #9 or #10 or #11 or #12 or #13 | 33514 |
| #15 | #6 and #14 | 19 |

| # | MEDLINE Ovid 18.01.2016 | |
|---|---|---|
| 1 | nursing homes/ or intermediate care facilities/ or skilled nursing facilities/ | 33459 |
| 2 | Homes for the Aged/ | 11704 |
| 3 | (nursing adj (home* or facilit*)).tw. | 25441 |
| 4 | (home? for the aged or home? for the elderly).tw. | 2343 |
| 5 | ((intermediate or long-term or longterm) adj care facilit*).tw. | 4314 |
| 6 | 2 or 3 or 4 or 5 | 36646 |
| 7 | exp Diagnostic Imaging/ | 1844124 |
| 8 | ((diagnostic or medical) adj (radio* or x-ray* or x ray*)).tw. | 4712 |
| 9 | exp Radiography/ | 673575 |
| 10 | (mobile adj (radio* or x-ray* or x ray*)).tw. | 217 |
| 11 | (portable adj (radio* or x-ray* or x ray*)).tw. | 356 |
| 12 | exp Telemedicine/ | 17681 |
| 13 | (telemedicine adj (radio* or x-ray* or x ray*)).tw. | 2 |
| 14 | 7 or 8 or 9 or 10 or 11 or 12 or 13 | 1862541 |
| 15 | 6 and 14 | 325 |

| # | Embase 1974 to 2016 Week 05 Ovid 05.02.2016 | |
|---|---|---|
| 1 | nursing homes/ or intermediate care facilities/ or skilled nursing facilities/ | 44749 |
| 2 | Homes for the Aged/ | 10530 |
| 3 | (nursing adj (home* or facilit*)).tw. | 32723 |
| 4 | (home? for the aged or home? for the elderly).tw. | 2990 |
| 5 | ((intermediate or long-term or longterm) adj care facilit*).tw. | 5518 |
| 6 | 2 or 3 or 4 or 5 | 46778 |
| 7 | exp Diagnostic Imaging/ | 126840 |
| 8 | ((diagnostic or medical) adj (radio* or x-ray* or x ray*)).tw. | 6246 |
| 9 | exp Radiography/ | 1007610 |
| 10 | (mobile adj (radio* or x-ray* or x ray*)).tw. | 265 |
| 11 | (portable adj (radio* or x-ray* or x ray*)).tw. | 395 |
| 12 | exp Telemedicine/ | 23252 |
| 13 | (telemedicine adj (radio* or x-ray* or x ray*)).tw. | 1 |

| | | |
|---|---|---|
| 14 | 7 or 8 or 9 or 10 or 11 or 12 or 13 | 1128654 |
| 15 | 6 and 14 | 576 |

| | Svemed+ 18.01.2016 | |
|---|---|---|
| **#** | **Search** | **Hits** |
| 1 | exp:"nursing homes" | 1121 |
| 2 | care facility | 733 |
| 3 | home of the aged | 530 |
| 4 | home of the elderly | 470 |
| 5 | "long term care facility" OR "long-term care facility" | 4 |
| 6 | "intermediate care facility" | 8 |
| 7 | %231 OR %232 OR %233 OR %234 OR %235 | 2051 |
| 9 | exp:"Diagnostic imaging" | 4907 |
| 13 | Portable AND (radio* OR x-ray OR x ray) | 1 |
| 14 | Mobile AND (radio* OR x-ray OR x ray) | 4 |
| 15 | exp:"Telemedicine" | 321 |
| 16 | Telemedicine AND (radio* OR x-ray OR x ray) | 3 |
| 17 | (Diagnostic OR meidcal) AND (radio* OR x-ray OR x ray) | 113 |
| 19 | exp:"Radiography" | 2585 |
| 20 | %239 OR %2313 OR %2314 OR %2315 OR %2316 OR %2317 OR %2319 | 5213 |
| 21 | %237 AND %2320 | 29 |

| | PubMed 05.02.2016 | |
|---|---|---|
| Search | Query | Items found |
| #11 | Search (#5) AND #10 | 1592 |
| #10 | Search (((#6) OR #7) OR #8) OR #9 | 1150432 |
| #9 | Search (((telemedicine) AND (radio* or x-ray* or x ray*))) | 530 |
| #8 | Search (((portable) AND (radio* OR x-ray* OR "x ray"))) | 1360 |
| #7 | Search (((mobile) AND (radio* OR x-ray* OR """"x ray""""))) | 4695 |
| #6 | Search ((((diagnostic OR medical)) AND (imaging OR radio* OR x-ray* OR "x ray"))) | 1147199 |
| #5 | Search (((#1) OR #2) OR #3) OR #4 | 113775 |

| | | |
|---|---|---|
| #4 | Search ("longterm care facility" OR "longterm care facilities" OR "long-term care facility" OR "long-term care facilities") | 4229 |
| #3 | Search ("intermediate care facility" OR "intermediate care facilities") | 782 |
| #2 | Search ("Home for the aged" OR "homes for the aged" OR "home for the elderly" OR "homes for the elderly") | 94187 |
| #1 | Search ("nursing home" OR "nursing homes" OR "nursing facility" OR "nursing facilities") | 43466 |

## Table A2: Searches in Google and Google Scholar

| | |
|---|---|
| 20.01.2016 - Google | |
| Mobile røntgentjenester til sykehjemspasienter (Norwegian) [Mobile radiography services for nursing home patients] | 143 |
| "Mobile radiology services" "nursing homes" | 342 |
| "mobile x-ray services" "nursing homes" | 1250 |
| 22.02.16 – Google Scholar | |
| Snowballing the eligible studies | 7 new |
| Total of records included in screening | 7 |

## Table A3: Excluded articles with reasons

| **Reference** | **Cause of exclusion** |
|---|---|
| Hellund, J.C., R. Tariq, and S. Sesseng, *Preliminary evaluation of the quality of the mobile radiographic images.* Michael quarterly, 2005. **2**(2): p.144-50 | Technical and/or diagnostic accuracy efficacy assessments |
| Loeb, M.B., et al., *Interobserver Reliability of Radiologists' Interpretations of Mobile Chest Radiographs for Nursing Home–Acquired Pneumonia.* Journal of the American Medical Directors Association, 2006. **7**(7): p. 416-419. | |
| CADTH, Mobile x-ray imaging versus fixed x-ray imaging in long-term care: clinical and cost-effectiveness. 2014. 4 Canadian Agency for Drugs and Technologies in Health (CADTH) http://onlinelibrary.wiley.com/o/cochrane/clhta/articles/HTA-32014000782/frame.html Accessed 18 Jan 2016 | Non-empirical |

| | |
|---|---|
| Lærum, F., *Sykehjemsrøntgen på hjul. [Nursing home radiography on wheels].* Michael quarterly, 2005. **2**: p. 168-89. | |
| Minniti, D. et al., *Progetto di radiologia domiciliare della Regione Piemonte: 3 anni di sperimentazione. [R@dhome of Piedmont Region: three years of experimentation]* Ann Ig, 2013. **(Suppl. 1)**: p. 271-276. | Covered by already included articles |
| Lærum, F., et al., *Moving equipment, not patients: Mobile, net-based digital radiography to nursing home patients*. International Congress Series, 2005. **1281**: p. 922-925. | |
| Verma, G., A.W. Chuck, and P. Jacobs, Tuberculosis screening for long-term care: a cost-effectiveness analysis. Int J Tuberc Lung Dis, 2013. **17**(9): p. 1170-7 | A screening program. |

## Table A4: Mixed Methods Appraisal Tool (MMAT) assessment of included studies.

| **Eklund et al** | MMAT criteria & one-page template | | | | |
|---|---|---|---|---|---|
| Types of mixed methods study components or primary studies | Methodological quality criteria (see tutorial for definitions and examples) | Responses | | | |
| | | Yes | No | Can't tell | Comments |
| Screening questions | Are there clear qualitative and quantitative research questions (or objectives*), or a clear mixed methods question (or objective*)? | x | | | Aim |
| | Do the collected data allow address the research question (objective)? E.g., consider whether the follow-up period is long enough for the outcome to occur (for longitudinal studies or study components). | x | | | |
| 4. Quantitative descriptive | 4.1. Is the sampling strategy relevant to address the quantitative research question (quantitative aspect of the mixed methods question)? | x | | | |
| | 4.2. Is the sample representative of the population understudy? | x | | | All included |
| | 4.3. Are measurements appropriate (clear origin, or validity known, or standard instrument)? | x | | | |
| | 4.4. Is there an acceptable response rate (60% or above)? | x | | | 100 % |
| Total score | | 100% **** | | | |

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(Additional file)

| **Lærum, Sager et al 2005** | MMAT criteria & one-page template | | | | |
|---|---|---|---|---|---|
| Types of mixed methods study components or primary studies | Methodological quality criteria (see tutorial for definitions and examples) | Responses | | | |
| | | Yes | No | Can't tell | Comments |
| Screening questions | Are there clear qualitative and quantitative research questions (or objectives*), or a clear mixed methods question (or objective*)? | x | | | Aim |
| | Do the collected data allow address the research question (objective)? E.g., consider whether the follow-up period is long enough for the outcome to occur (for longitudinal studies or study components). | x | | | |
| 4. Quantitative descriptive | 4.1. Is the sampling strategy relevant to address the quantitative research question (quantitative aspect of the mixed methods question)? | x | | | |
| | 4.2. Is the sample representative of the population understudy? | x | | | |
| | 4.3. Are measurements appropriate (clear origin, or validity known, or standard instrument)? | | | x | Unclear |
| | 4.4. Is there an acceptable response rate (60% or above)? | x | | | |
| Total score | | 75% *** | | | |

| **Montalto et a**l 2015 | MMAT criteria & one-page template | | | | |
|---|---|---|---|---|---|
| Types of mixed methods study components or primary studies | Methodological quality criteria (see tutorial for definitions and examples) | Responses | | | |
| | | Yes | No | Can't tell | Comments |
| Screening questions | Are there clear qualitative and quantitative research questions (or objectives*), or a clear mixed methods question (or objective*)? | x | | | Aim |
| | Do the collected data allow address the research question (objective)? E.g., consider whether the follow-up period is long enough for the outcome to occur (for longitudinal studies or study components). | x | | | |

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(Additional file)

| | | | | | |
|---|---|---|---|---|---|
| 4. Quantitative descriptive | 4.1. Is the sampling strategy relevant to address the quantitative research question (quantitative aspect of the mixed methods question)? | x | | | |
| | 4.2. Is the sample representative of the population understudy? | x | | | Top 30 users could overestimate the impact (risk of bias). |
| | 4.3. Are measurements appropriate (clear origin, or validity known, or standard instrument)? | x | | | |
| | 4.4. Is there an acceptable response rate (60% or above)? | x | | | |
| Total score | | 100% **** | | | |

| **Lærum, Åmdal et al 2005** | MMAT criteria & one-page template | | | | |
|---|---|---|---|---|---|
| Types of mixed methods study components or primary studies | Methodological quality criteria (see tutorial for definitions and examples) | Responses | | | |
| | | Yes | No | Can't tell | Comments |
| Screening questions | Are there clear qualitative and quantitative research questions (or objectives*), or a clear mixed methods question (or objective*)? | x | | | |
| | Do the collected data allow address the research question (objective)? E.g., consider whether the follow-up period is long enough for the outcome to occur (for longitudinal studies or study components). | x | | | Limited data compared to the scope of the third research question. |
| 4. Quantitative descriptive | 4.1. Is the sampling strategy relevant to address the quantitative research question (quantitative aspect of the mixed methods question)? | x | | | Additional information provided from the corresponding author |

| | | | | | |
|---|---|---|---|---|---|
| | 4.2. Is the sample representative of the population understudy? | x | | | Additional information provided from the corresponding author |
| | 4.3. Are measurements appropriate (clear origin, or validity known, or standard instrument)? | x | | | Additional information provided from the corresponding author |
| | 4.4. Is there an acceptable response rate (60% or above)? | x | | | Additional information provided from the corresponding author |
| Total score | | 100%**** | | | |

| **Ricauda et al, 2011** | MMAT criteria & one-page template (to be included in appraisal forms) | | | | |
|---|---|---|---|---|---|
| Types of mixed methods study components or primary studies | Methodological quality criteria (see tutorial for definitions and examples) | Responses | | | |
| | | Yes | No | Can't tell | Comments |
| Screening questions | Are there clear qualitative and quantitative research questions (or objectives*), or a clear mixed methods question (or objective*)? | x | | | Aim |
| | Do the collected data allow address the research question (objective)? E.g., consider whether the follow-up period is long enough for the outcome to occur (for longitudinal studies or study components). | x | | | |
| 2. Quantitative randomized controlled (trials) | 2.1. Is there a clear description of the randomization (or an appropriate sequence generation)? | x | | | |

| | | | | | |
|---|---|---|---|---|---|
| | 2.2. Is there a clear description of the allocation concealment (or blinding when applicable)? | x | | x | Blinded for assessment of image quality, but unclear for post examination Delirium Rating Scale assessment |
| | 2.3. Are there complete outcome data (80% or above)? | x | | | |
| | 2.4. Is there low withdrawal/drop-out (below 20%)? | x | | | |
| Total score | | 100%**** | | | |

| **Forat et al 2010** | MMAT criteria & one-page template | | | | |
|---|---|---|---|---|---|
| Types of mixed methods study components or primary studies | Methodological quality criteria (see tutorial for definitions and examples) | Responses | | | |
| | | Yes | No | Can't tell | Comments |
| | | | | | |
| Screening questions | Are there clear qualitative and quantitative research questions (or objectives*), or a clear mixed methods question (or objective*)? | x | | | Aim |
| | Do the collected data allow address the research question (objective)? E.g., consider whether the follow-up period is long enough for the outcome to occur (for longitudinal studies or study components). | x | | | |
| 4. Quantitative descriptive | 4.1. Is the sampling strategy relevant to address the quantitative research question (quantitative aspect of the mixed methods question)? | | | x | Unclear connection between aim and questions asked |
| | 4.2. Is the sample representative of the population understudy? | x | | | |

| | | | | | |
|---|---|---|---|---|---|
| | 4.3. Are measurements appropriate (clear origin, or validity known, or standard instrument)? | | x | | |
| | 4.4. Is there an acceptable response rate (60% or above)? | | x | | |
| Total score | | 25%* | | | |

| **Thingnes & Stalsberg** 2010 | MMAT criteria & one-page template | | | | |
|---|---|---|---|---|---|
| Types of mixed methods study components or primary studies | Methodological quality criteria (see tutorial for definitions and examples) | Responses | | | |
| | | Yes | No | Can't tell | Comments |
| Screening questions | Are there clear qualitative and quantitative research questions (or objectives*), or a clear mixed methods question (or objective*)? | x | | | |
| | Do the collected data allow address the research question (objective)? E.g., consider whether the follow-up period is long enough for the outcome to occur (for longitudinal studies or study components). | x | | | |
| 1. Qualitative | 1.1. Are the sources of qualitative data (archives, documents, informants, observations) relevant to address the research question (objective)? | x | | | |
| | 1.2. Is the process for analyzing qualitative data relevant to address the research question (objective)? | x | | | |
| | 1.3. Is appropriate consideration given to how findings relate to the context, e.g., the setting, in which the data were collected? | x | | | |
| | 1.4. Is appropriate consideration given to how findings relate to researchers' influence, e.g., through their interactions with participants? | | x | | |
| Total score | | 75% *** | | | |

## Table A5: CASP appraisal of economic evaluations included in the review.

| **Price Waterhouse Coopers, 2006** | | Yes | Can't tell | No |
|---|---|---|---|---|
| Is the economic evaluation valid? | 1. Was a well-defined question posed? | X | | |
| | 2. Was a comprehensive description of the competing alternatives given? | X | | |

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(Additional file)

| | | | | |
|---|---|---|---|---|
| How were costs and consequences assessed and compared? | 3. Does the paper provide evidence that the programme would be effective (i.e. would the programme do more good than harm? | X | | |
| | 4. Were the effects of the intervention identified, measured and valued appropriately? | X | | |
| | 5. Were all important and relevant resources required and health outcome costs for each alternative identified, measured in appropriate units and valued credibly? | X | | |
| | 6. Were costs and consequences adjusted for different times at which they occurred (discounting)? | X | | |
| | 7. What were the results of the evaluation? | X | | |
| | 8. Was an incremental analysis of the consequences and cost of alternatives performed? | X | | |
| | 9. Was an adequate sensitivity analysis performed? | X | | |
| Will the results help in purchasing services for local people? | 10. Is the programme likely to be equally effective in your context or setting? | X | | |
| | 11. Are the costs translatable to your setting? | X | | |
| | 12. Is it worth doing in your setting? | X | | |
| Total score | | 100% | **** | |

| **Randers 2005** | | Yes | Can't tell | No | Comment |
|---|---|---|---|---|---|
| Is the economic evaluation valid? | 1. Was a well-defined question posed? | X | | | |
| | 2. Was a comprehensive description of the competing alternatives given? | X | | | |
| How were costs and consequences assessed and compared? | 3. Does the paper provide evidence that the programme would be effective (i.e. would the programme do more good than harm? | X | | | To the extent relevant in this paper |
| | 4. Were the effects of the intervention identified, measured and valued appropriately? | X | | | To the extent relevant |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | in this paper |
| | 5. Were all important and relevant resources required and health outcome costs for each alternative identified, measured in appropriate units and valued credibly? | X | | | To the extent relevant in this paper |
| | 6. Were costs and consequences adjusted for different times at which they occurred (discounting)? | | | X | |
| | 7. What were the results of the evaluation? | X | | | |
| | 8. Was an incremental analysis of the consequences and cost of alternatives performed? | X | | | |
| | 9. Was an adequate sensitivity analysis performed? | | | X | |
| Will the results help in purchasing services for local people? | 10. Is the programme likely to be equally effective in your context or setting? | X | | | |
| | 11. Are the costs translatable to your setting? | X | | | |
| | 12. Is it worth doing in your setting? | X | | | |
| Total score | | 75% | *** | | |

| **Dozet, 2015 (abstract)** | | Yes | Can't tell | No | Comment |
|---|---|---|---|---|---|
| Is the economic evaluation valid? | 1. Was a well-defined question posed? | X | | | |
| | 2. Was a comprehensive description of the competing alternatives given? | X | | | |
| How were costs and consequences assessed and compared? | 3. Does the paper provide evidence that the programme would be effective (i.e. would the programme do more good than harm? | | X | | Corresponding author has been contacted for more information – but |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | this has not been given |
| | 4. Were the effects of the intervention identified, measured and valued appropriately? | | X | | |
| | 5. Were all important and relevant resources required and health outcome costs for each alternative identified, measured in appropriate units and valued credibly? | | X | | |
| | 6. Were costs and consequences adjusted for different times at which they occurred (discounting)? | | X | | |
| | 7. What were the results of the evaluation? | X | | | |
| | 8. Was an incremental analysis of the consequences and cost of alternatives performed? | X | | | |
| | 9. Was an adequate sensitivity analysis performed? | | X | | |
| Will the results help in purchasing services for local people? | 10. Is the programme likely to be equally effective in your context or setting? | X | | | |
| | 11. Are the costs translatable to your setting? | X | | | |
| | 12. Is it worth doing in your setting? | X | | | |
| Total score | | 25% | * | | |

# Paper II

Kjelle, E., Lysdahl, K.B. & Olerud, H.M. Impact of mobile radiography services in nursing homes on the utilization of diagnostic imaging procedures. Submitted to BMC Health Services Research.

**Title:** Impact of Mobile Radiography Services in Nursing Homes on the Utilisation of Diagnostic Imaging Procedures

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**Abstract**

*Background*: In the last decade, mobile radiography services have been introduced in nursing homes in several countries. Earlier research found an underutilisation of diagnostic imaging among nursing home residents. However, the effects of introducing mobile radiography services on the use of diagnostic imaging are unknown. The purpose of this study was to determine the utilisation of diagnostic imaging among nursing home residents and if there are any differences between hospitals with and without a mobile radiography service.

*Methods*: Data for 2015 were collected from the radiological information systems of 11 hospitals. The data included information on the anatomical region/organ/organ system, modality, and information on where the examination took place. Using nursing home beds as a proxy for nursing home residents' differences in the use of diagnostic imaging in areas with hospitals with and without mobile radiography services was analysed. The chi-squared test was used to compare the areas.

*Results*: From 11,066 examinations of nursing home residents, 87% were plain radiographs, 8% were CT scans, and 4% were ultrasound examinations. In areas with mobile radiography services, there was a significantly higher proportion of diagnostic imaging used per nursing home bed, 50% per bed compared to 36% per bed in areas without; $p$=<0.001. Furthermore, in areas with mobile radiography services, there was a significantly lower proportion of CT and ultrasound used per nursing home bed, 2.5% and 1.4% respectively per bed compared to 4.7% and 2.2% respectively per bed in areas without; $p$=<0.001.

*Conclusions*: When a mobile radiography service is present, there are a higher proportion of diagnostic imaging examinations among nursing home residents. Nursing home residents undergo plain radiographs in 87% of the cases. The proportions of plain radiographs are significantly higher when a mobile radiography service is present. The proportion of more advanced imaging techniques such as CT and ultrasound are lower when mobile radiography

services are available. The higher use of diagnostic imaging is most likely appropriate because of an underuse of diagnostic imaging among nursing home residents compared to the general population. Further research is necessary on how to improve diagnostic imaging services for nursing home residents.

**Keywords:** mobile radiography service, nursing home, nursing home resident, telemedicine, diagnostic imaging, mobile health unit.

## Background

According to the European Union demography report (1) an ageing of the population is expected over the few next decades, which may lead to an increase in people living in healthcare institutions (1, 2). Demographic changes in the Western world makes high-quality and cost-effective services an important factor in order to maintain sustainable healthcare systems (3, 4). In 2016, 42,644 people resided in care institutions for the elderly in Norway, including both long- and short-term stays. Residents in different types of care institutions in Norway, hereafter called nursing homes, have a mean age of 82.3 years (5). These residents have a greater need for specialised healthcare services compared to the rest of the population. This is due to the fact that up to 80% are living with dementia and/or several co-morbidities (6-10). According to Graverholt et al. (8), 16-62% of nursing home residents are admitted to a hospital for acute care every year, of which up to 40% could be avoided. Nursing home residents can be admitted to a hospital for three reasons: diagnostic, treatment to improve function and life expectancy, or palliative treatment (6). In 2013, the most common reasons for acute admittance of nursing home residents in a Norwegian setting were diseases of the respiratory system (19.8%), injury, poisoning, and certain other consequences of external causes (mostly fall injuries and hip fractures) (17.8%), diseases of the circulatory system (16.5%), and diseases of the digestive system (9.9%) (8). According to Ranhoff and Linnsund

(6), there are two cases where hospitalisation benefits most nursing home residents: hip fractures and severe anaemia. Otherwise, the benefit of admittance depends on the residents' condition and most would be better off treated in the nursing home (6).

According to Wang et al. (11), approximately 72% of nursing home residents visiting an emergency department in the US needed diagnostic imaging; of these, approximately 85% needed X-ray examinations and 35% needed CT scans. Thus, diagnostic imaging is a specialist service useful to these residents. In the general population, international trends in diagnostic imaging show a decrease in the use of plain radiographs and fluoroscopy and an increase in the use of CT and MRI (12-17). However, for nursing home residents, plain radiographs seem to be the most important imaging tests (11, 18).

Furthermore, Lærum, Åmdal (19) indicated an underuse of diagnostic imaging for nursing home residents compared to the general population. This is quite the opposite of expectations based on nursing home residents' health status, indicating a need for easier access to imaging services (19). Earlier research showed that access to imaging services influenced the utilisation rate (20, 21). To improve access, a mobile radiography service to nursing homes was piloted in Oslo in 2004 (19). In this service, a radiographer brought a portable X-ray machine and conducted plain radiographs in the residents' rooms (22). At present, such services operate in Australia, Italy, Norway, Sweden, and Switzerland (18, 22-28). According to earlier research, mobile radiography is beneficial for nursing home residents and leads to reduced healthcare costs (22, 24, 29).

At present, the general population receives 1.1 examinations per caput in Europe (13). However, we do not know how mobile radiography services affect the number and type of diagnostic imaging examinations nursing home residents receive. Information on the utilisation of diagnostic imaging may provide a better basis for designing healthcare services for this fragile patient group.

The aim of this study was to describe the overall utilisation of diagnostic imaging in the population of nursing home residents and to explore if there are any differences between the type and number of examinations provided by hospitals with and without mobile radiography services.

## Methods

### *Data collection*

Data were requested from the radiology information systems (RIS) of 12 different hospitals/hospital trusts from the four healthcare regions of Norway. Six had a mobile radiography service combined with a hospital-based service and six had a hospital-based service only. Eleven hospitals delivered data and are included in the study, six with and five without mobile services in the surrounding areas.

The data included all diagnostic imaging procedures for nursing home residents in 2015. The data were recorded using the Norwegian classification of radiological procedures (NCRP) (30). This system provides detailed information on anatomical region/organ/organ system, modality, and whether the examination was for diagnostic or treatment purposes (30). The data were allocated to the following categories: plain radiographs (2D images), computed tomography (CT), ultrasound, magnetic resonance imaging (MRI), nuclear medicine, and others (including fluoroscopy, interventional procedures, and mammography). In addition, information on the place of examination (a hospital or a nursing home) was provided. All of the hospitals except one provided full datasets. This hospital provided data on the mobile service only.

The hospitals and the areas they cover with respect to imaging services were sorted into two categories, those with mobile radiography services and those without. Information on these two categories is presented in Table 1. In the category with mobile radiography service, three of the five mobile services did not cover all of the nursing homes in their area. This differs

with each hospital's organisation of the mobile radiography service and contracts with municipalities (31). The number of overall and types of examination are presented in plain numbers. For the analyses comparing the examination rates between the two categories, aggregated data on the nursing home beds in the areas the hospitals cover was used as the denominator, that is, the calculated proportion of the examinations per bed. Nursing home beds were used as proxies for the nursing home residents, as the RIS data from the hospitals did not include information on the individual residents. The number of residents may be higher than the number of beds due to short or intermediate time stays or residents dying. There were 24,805 nursing home beds in this study in the areas covered by the included hospitals in 2015 (32).

**Table 1**: Information on the included areas covered by hospitals with and without mobile radiography services.

| | With mobile radiography service (% covered by mobile service) | Without mobile radiography service |
|---|---|---|
| Nursing home beds, n | 14,500 (86) | 10,305 |
| Mean population density (per $km^2$) | 412.1 | 125.5 |

*Statistical analysis*

To perform the comparative analysis, the data were divided into the two categories, with or without mobile radiography service. Microsoft Excel (2013) was used to assess the descriptive statistics. R (R Core Team, 2018) was used to perform 2-tailed chi-squared tests in the difference of proportion. *P* values less than 0.05 were considered significant.

*Ethics*

Regional Committees for Medical and Health Research Ethics (REC) approved the dispensation from professional secrecy (12 February 2016, project no. 2468) and the Norwegian Centre for Research Data (NSD) approved the data collection and handling for

this study (15 February 2016, project no. 45571). In addition, each hospital's local research committee approved the data collection.

## Results

A total of 11,066 diagnostic imaging examinations were performed by the included hospitals on nursing home residents in 2015. The hospitals covered 24,805 nursing home beds, for an average number of 0.45 examinations per nursing home bed. Figure 1 shows the proportion per modality. Plain radiographs were the most common examination (87%), followed by CT (8%) and ultrasound (4%) as the third most common examination. MRI, nuclear medicine, and others (fluoroscopy, interventional procedures, and mammography) accounted for 1% or less of the examinations performed.

Please insert Figure 1 here

### *Overall use of diagnostic imaging*

There were 14,500 nursing home beds in areas with mobile radiography services and 10,305 nursing home beds in areas without mobile radiography (32). Using the chi-squared test, the two categories were compared and the results are presented in Table 2. Out of all of the examinations, the proportion was significantly higher in the category with mobile radiography services (50% per bed) compared to the category without (36% per bed), $\chi^2$(df=1, n=11,066)=470.39, $p$=<0.001. In other words, up to half of the residents occupying the nursing home beds were likely to receive an examination during one year. The proportion of plain radiograph examinations was significantly higher in the category with mobile radiography services, $\chi^2$(df=1, n=9,600)=736.22, $p$=<0.001. In the category with mobile radiography services, the proportion of CT and ultrasound examinations was significantly lower $\chi^2$(df=1, n=851)=83.33, $p$=<0.001 and $\chi^2$ (df=1, n=431)=20.08, $p$=<0.001, respectively. Nuclear medicine, MRI, and other examinations showed no significant differences in proportion.

174 **Table 2**: Comparison of the differences in proportion of examinations per nursing home bed

| | With mobile radiography service | | Without mobile radiography service | | Diff. (% point) | 95% Confidence interval | | *P* value |
|---|---|---|---|---|---|---|---|---|
| | n | Proportion of examinations per bed (%) | n | Proportion of examinations per bed (%) | | Minimum | Maximum | |
| Nursing home beds | 14,500 | | 10,305 | | | | | |
| All examinations | 7,306 | 50.00 | 3,760 | 36.00 | 14.0 | 12.7 | 15.10 | <0.001 |
| Plain radiographs | 6,638 | 45.80 | 2,962 | 28.70 | 17.10 | 15.8 | 18.20 | <0.001 |
| CT | 368 | 2.50 | 483 | 4.70 | -2.20 | -2.6 | -1.70 | <0.001 |
| Ultrasound | 206 | 1.40 | 225 | 2.20 | -0.80 | -1.0 | -0.40 | <0.001 |
| MRI | 53 | 0.37 | 43 | 0.42 | -0.05 | -0.2 | 0.10 | 0.587 |
| Nuclear medicine | 27 | 0.20 | 32 | 0.30 | -0.10 | -0.3 | 0.01 | 0.065 |
| Other | 14 | 0.10 | 15 | 0.15 | -0.05 | -0.15 | 0.05 | 0.355 |

175

176 *Plain radiographs*

177 A total of 9,600 plain radiographs were conducted on nursing home residents. Of these, 6,638
178 were in the category with mobile radiography services, and >73% (n=5,196) of the plain
179 radiographs were performed by the mobile radiography service. The most frequent
180 examinations were the chest, hip, and pelvis, which constituted just over 22% (n=2,131), 22%
181 (n=2,110), and approximately 18% (n=1,744), respectively (Figure 2). These were followed
182 by approximately 27% (n=2,580) of examinations of the extremities (for example, the
183 shoulder, wrist, ankle, and foot), spine just over 8% (n=796), and abdomen approximately 2%
184 (n=175). Examinations of for example the sternum, scapula, and clavicular bone with a total
185 score of <20 examinations per year have been grouped together in "Other"; these amounted to
186 <1% of the examinations.

187 Please insert Figure 2 here

188

189 *CT*

190 There were 851 CT examinations performed on nursing home residents in 2015.
191 Approximately 41% (n=354) of the CT examinations were of the brain and approximately

24% (n=203) were of the abdominal/pelvic areas (Table 3). Furthermore, approximately 21% of the examinations were combined CT examinations (n=72), CTs of the spine (n=45), and CTs of the extremities (n=31). Examinations of for example the urinary system and angiograms with a frequency of <20 examinations per year have been grouped together in "CT other" and constituted just over 9% of the examinations.

**Table 3**: An overview of types of CT examinations performed divided by category and in total

| | With mobile radiography service, n | Without mobile radiography service, n | Total (%) |
|---|---|---|---|
| CT brain | 153 | 201 | 354 (41.6) |
| CT abdomen/pelvis | 79 | 124 | 203 (23.9) |
| CT combinations | 34 | 38 | 72 (8.5) |
| CT chest | 35 | 33 | 68 (8.0) |
| CT spine | 22 | 23 | 45 (5.3) |
| CT extremities | 9 | 22 | 31 (3.5) |
| CT other* | 36 | 42 | 78 (9.2) |
| Total | 368 | 483 | 851 (100) |

*Examination types with a frequency of <20 per year.

*Ultrasound examinations*

Of the 431 ultrasound examinations performed on nursing home residents, approximately 36% were examinations of the veins in the lower extremities (n=156) and approximately 33% were of the abdominal organs (n=143) (Table 4). Furthermore, just over 8% were examinations of the urinary system (n=36) and approximately 7% were of the mammae/axilla (n=32). Examinations of for example the skin and male genitalia with a frequency of <20 examinations per year have been grouped together in "Ultrasound other" and amounted to just under 15% of the examinations.

**Table 4:** An overview of types of ultrasound examinations divided by category and in total

| | With mobile radiography service, n | Without mobile radiography service, n | Total (%) |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Ultrasound veins in lower extremities | 80 | 76 | 156 (36.2) |
| Ultrasound abdominal area | 61 | 82 | 143 (33.2) |
| Ultrasound urinary system | 12 | 24 | 36 (8.3) |
| Ultrasound mammae/axilla | 21 | 11 | 32 (7.4) |
| Ultrasound other* | 32 | 32 | 64 (14.9) |
| Total | 206 | 225 | 431 (100.0) |

*Examination types with a frequency of <20 per year.

## Discussion

### *Overall use of diagnostic imaging*

Earlier research suggested an underuse of diagnostic imaging among nursing home residents compared to the general population (19). This was assumed to be caused by the fact that 10-20% of residents were unable to undergo an appropriate examination at a hospital (19, 22, 24). This was due to either the resident's condition or a lack of personnel/family to accompany them (19, 22). Thus, a higher proportion in the use of diagnostic imaging in general when mobile radiography was available, as shown in this study, seems appropriate. In line with earlier research, easy access to imaging services increases their use (20, 21). When a mobile radiography service was present, there was a higher proportion of imaging services in general, 50% examinations per nursing home bed, compared to 36% examinations per bed if in-hospital examination was the only possibility. The number of examinations per nursing home resident was even lower based on the assumption that there was more than one resident per bed each year. However, compared to the general population in Europe where 1.1 examinations per caput are made annually (including dental imaging) (13) or an average of 0.9 examinations per person per year in Norway (33), with nursing home residents receiving less than half, clearly indicates an overall underuse of diagnostic imaging in this population.

### *Variation in use of modalities*

Earlier research indicated that plain radiographs were the most important type of examination for nursing home residents (8, 11). In this study, 87% of the examinations were plain

radiographs. In the areas with mobile radiography services, the proportion of plain radiographs was approximately 46%, while the proportion was almost 29% in areas without this service. Examinations of the chest, hip, pelvis, and extremities were the most common. This is consistent with the conditions for which nursing home residents are most commonly admitted (8).

CT examinations of the head and abdominal/pelvic area were the most common. In ultrasound, the veins of the lower extremities and the abdominal organs were most commonly examined. When a mobile radiography service was available, there was a significantly smaller proportion of CT and ultrasound. This indicated that residents transferred to a hospital are more likely to be examined with more advanced imaging technologies. Again, this complies with earlier research showing that better access increased use (20, 21). This difference could indicate that residents transferred to a hospital slightly overuse CT and ultrasound examinations beyond what is needed to obtain a diagnosis. On the other hand, there may be an underuse of more advanced imaging when a mobile radiography service is present.

There were no data on the medical indication for the examinations available in this study; thus, the appropriateness could not be assessed. However, earlier research on nursing home residents' reasons for admittance showed that respiratory infections, chronic obstructive pulmonary disease, injuries (fractures), and diseases of the circulatory system were the most common conditions (6, 8). According to Ranhoff and Linnsund (6), with most of these conditions except hip fractures, hospitalisation does not benefit most residents as long as adequate treatment is provided in the nursing home. Adequate nursing home treatment also benefits residents on a psychosocial level (22, 34). Nursing home residents and especially those living with dementia need a familiar environment to feel safe and cared for (34, 35). Transfer to a hospital for an examination or admission could cause exhaustion, delirium,

and/or injuries (7, 9, 19, 27, 35). Thus, residents may have a higher quality of life when transfer to a hospital can be avoided (34).

To increase access to imaging technologies for nursing home residents, there is the possibility of having mobile CT or ultrasound units. Mobile CT units in ambulances for diagnosing stroke patients are available in Germany, Norway, and the US (36-38). CT of the head amounts to >40% of CT examinations of nursing home residents, so using these mobile CT units could help increase access and at the same time reduce unnecessary transfers to a hospital. Ultrasound machines are easier to transfer than both CT and X-ray equipment. With qualified personnel on the mobile radiography service, both plain radiographs and ultrasound examinations could be performed by the same mobile unit, thus further reducing the number of resident transfers to a hospital.

*Limitations of the data*

The sample used in this study included examinations of nursing home residents from 11 hospitals. Data were collected from hospitals in different parts of Norway, with different population densities and thus different travel distances from nursing homes to a hospital. Travel distance may affect the use of mobile radiography services as well as the frequency of transfers to a hospital due to the effect of easy access (20, 21). Mobile radiography services in Norway are established in urban areas (22). Thus, some of the increased use of diagnostic imaging could be explained by easier access to the service. Furthermore, in these urban areas, there are private hospitals and imaging centres in addition to the public hospital from which no data were collected. Thus, the number of examinations in this category could have been underestimated.

Two of the five hospitals with mobile radiography services provided this service to all of the surrounding nursing homes. The other three covered just some of the surrounding nursing homes (31), amounting to 86% coverage. Thus, access also differed within the included

hospitals in this category. Again, this could have led to an underestimation of the proportion of examinations possible when a mobile radiography service was available. One hospital presented data on the mobile radiography service only. To obtain a better overview of the area with missing data, the hospital reporting mobile services were combined with data from another hospital in the same city to represent the surrounding area in question. However, the total numbers of examinations were underestimated in this area.

The individual physician's referral rate could affect the number of examinations conducted. In different nursing homes, the same condition could be handled differently, and this could affect the referral rate. This also could affect both categories equally; however, there is no way of knowing the effect of this phenomenon. In an effort to reduce this effect, several hospitals from different parts of Norway were included in each category.

Notwithstanding their limitations, the data provided a good basis for comparing the two categories. The different hospitals used the same coding system; this secured a uniform data format and assisted an accurate count. In addition, all parts of the country were included, rendering the results generalisable at least to similar settings.

## Conclusions

This study showed the influence of mobile radiography services on the use of diagnostic imaging. There was a substantial difference in the use of imaging services between the categories. With mobile radiography services, the proportion of imaging used per nursing home bed are higher than without. This was due to a greater proportion of plain radiographs in areas with mobile radiography services. Nursing home residents needed plain radiographs in 87% of the examinations. Chest, hip, pelvis, and the extremities were most common plain radiograph examinations performed. Furthermore, the proportion of CT and Ultrasound examinations were significantly lower when a mobile radiography service was available. The findings indicated a need for increased access through mobile radiography services for

nursing home residents and suggested possibilities for expanding services to include CT and ultrasound. However, further research is necessary on how to improve diagnostic imaging services for nursing home residents.

**List of Abbreviations**

CT – Computed Tomography

MRI – Magnetic resonance imaging

RIS – Radiology Information System

## Declarations

### Ethics approval and consent to participate

Regional Committees for Medical and Health Research Ethics - 12 February 2016, project no. 2468

Norwegian Centre for Research Data -15 February 2016, project no. 45571.

Each hospital's local research committee approved the data collection.

### Consent for publication

It was not possible to contact each patient because information on individual level was not available in the data.

### Availability of data and material

The dataset generated and analysed during the current study are not publicly available due to participant anonymity issues, but are available from the corresponding author on reasonable request.

## Competing interests

The authors declare that they have no competing interests.


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This study is part of a PhD fellowship at the University of South-Eastern Norway. The funding body did not participate in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.


## Authors' contributions

All authors participated in planning this study. EK collected data from the hospitals. All authors participated in analysing the data. EK wrote the main parts of the manuscript. All authors read and approved the final manuscript.


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# Figures

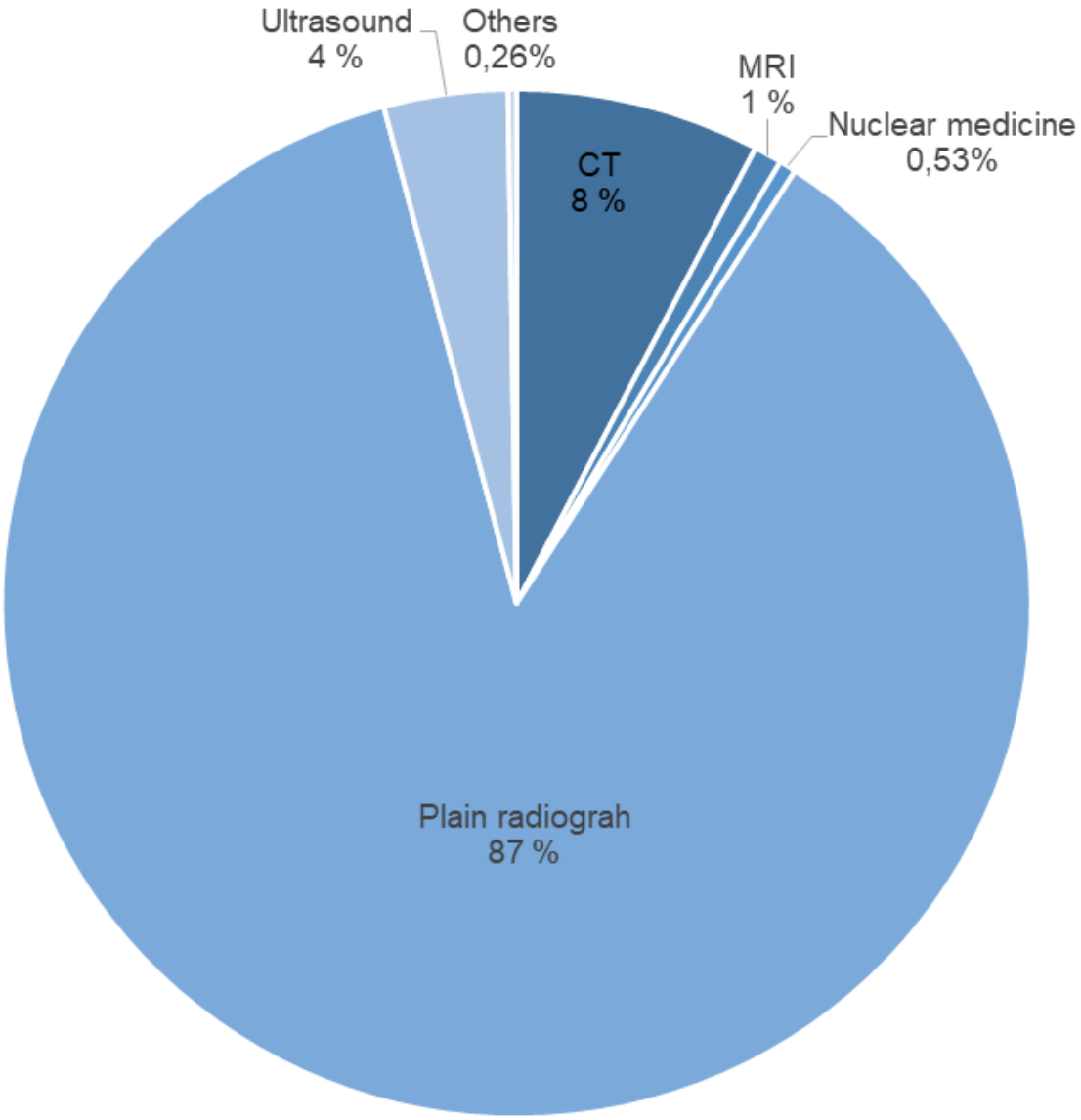
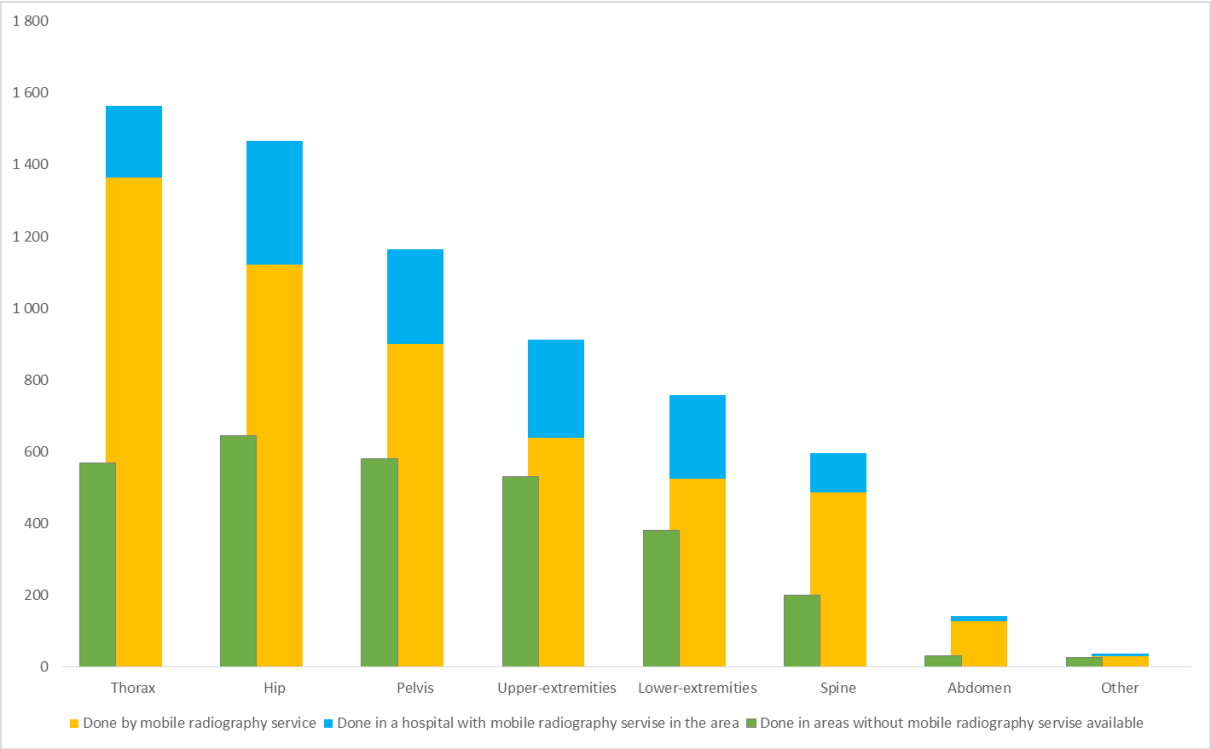



**Figure 1:** Proportion of different modalities of the 11,084 examinations of nursing home residents in 2015




444

445 **Figure 2**: Overview of the types of plain radiograph examinations in areas with and without

446 mobile services

447 Legend: "Other" includes examination types with a frequency of <20 per year

448

# Paper III

Kjelle, E., Kleven, L., Olerud, H.M. & Melberg, H.O. (2018). Cost-analysis of mobile radiography services for nursing home residents in Southeast Norway. *Journal of Evaluation in Clinical Practice,* 1-7. doi: 10.1111/jep.13058

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ORIGINAL PAPER

WILEY Journal of Evaluation in Clinical Practice
International Journal of Public Health Policy and Health Services Research

# Cost analysis of mobile radiography services for nursing home residents in Southeast Norway

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## Abstract

**Rationale, aims, and objective:** Telemedicine applications, such as a mobile radiography service, provide a new way of organizing healthcare services. In order to provide safe and personalised care for nursing home residents during X-ray examinations, mobile radiography services have been implemented. The objective of this study was to analyse the costs of X-ray examinations and treatments for nursing home residents when comparing hospital-based imaging with a combination of hospital-based imaging and a mobile radiography service in Southeast Norway.

**Methods:** A decision model was developed using the software TreeAge Pro. The model included two alternatives: the mobile radiography service in combination with hospital-based imaging and hospital-based imaging alone. The treatment needed based on the examination results could be given either in the nursing home or at the hospital. Probabilities and costs in the model were derived from previous research, various reports, and hospital data from the Southeast region of Norway. Monte Carlo simulations of 1000 residents were run through the model, and statistical analyses were applied.

**Results:** The analysis showed a mean cost of €2790 per resident for the hospital-based service alone. For mobile and hospital-based services combined, the mean cost was €1946 per resident, including examinations and the immediate treatment given. This difference in costs was significant ($p < 0.001$).

**Conclusion:** A mobile radiography service in nursing homes provides a safe, high quality health care service. The result of this study showed there was a 30% cost-reduction by implementing the mobile radiography service

KEYWORDS

cost analysis, mobile health care unit, mobile radiography, modelling, nursing homes, X-ray

  

## 1 | INTRODUCTION

Demographic changes in Western societies has led to an aging population, and the number of people living in nursing homes is expected to increase.[1-3] This highlights the need for a better organization of health care services at the same time that high-quality health care is delivered.[1] In Norway today, >80% of residents in different kinds of short- and long-term aged care facilities (hereafter known as nursing homes) suffer from dementia in addition to several other chronic illnesses.[4-6] Furthermore, these residents have a high incidence of injuries due to falling or acute illness such as infections and cardiovascular incidents.[4,6,7] Earlier research has shown that 60% of nursing home residents in Norway are admitted to a hospital every year.[5] Hospitalization of nursing home residents was mainly due to falls, respiratory infections, or digestive system diseases.[4] Conventional X-ray examinations such as 2D chest, musculoskeletal, and abdominal images are important diagnostic tests for these conditions (hereafter called X-ray examinations).[7,8] Hip fractures and severe pneumonia are the two most common reasons for nursing home residents to receive X-ray examinations at the hospital.[5]

According to statistics from the hospital trusts (E. Kjelle et al, unpubl. observ.), X-ray examinations were the most commonly used imaging service for nursing homes residents in 2015. Imaging services using conventional X-ray equipment can be provided in different ways. Today, nursing home residents in need of an X-ray examination are usually transferred to a hospital. An examination in a hospital allows for easy access to other specialist treatments and diagnostic tests.[8] However, for these fragile residents and especially for those living with dementia, new surroundings such as the imaging department may lead to anxiety, delirium, and injuries.[7,9,10] In addition, inpatient treatment at hospital are more costly than treatment in a nursing home.[11] The alternative would be a mobile radiography service, where a radiographer performs the X-ray examination in the residents' room at the nursing home,[10,12-14] (with an adequate quality image).[10,12,15] Thus, this would allow residents to remain within the familiar environment of the nursing home. According to previous research, a mobile radiography service may reduce the number of hospitalizations and reduce the number of residents that develop delirium.[16] The imaging department at the hospital is responsible for the investment costs of a mobile radiography service (a vehicle, X-ray equipment, and operation costs). The benefits that are gained from less transportation and hospitalization occur in the other departments or institutions.[16-19]

There is a relatively small body of literature concerning the costs of mobile radiography services. Three publications from Norway and Sweden have compared the cost of examining residents using a mobile radiography service with the cost of outpatient examinations in hospital.[20-22] Previous research has established that a mobile radiography service reduces the cost per examination in urban areas,[20-22] but few, if any, have investigated the costs of mobile radiography service in sparsely populated areas. Furthermore, the cost of the treatment after the examination has not been taken into account.[20-22]

The objective of this study was to analyse the costs with a societal perspective of X-ray examination and treatment of nursing home residents. Two alternatives were compared, including a hospital-based service and a combination of hospital-based and mobile radiography services.

## 2 | METHODS AND MATERIALS

### 2.1 | Institutional setting in Southeast Norway

Southeast Norway has a population of approximately 2.95 million people (56% of the Norwegian population), in an area of 111 009 km$^2$. On average, 4.4% of the population are >80 years old, and the mean age of nursing home residents in Norway is 82.3 years old. In Southeast Norway, 21 393 people resided in nursing homes in 2016. The region contains both densely and sparsely populated areas.

Mobile radiography services were implemented in five out of eight public hospital trusts in Southeast Norway (Oslo University Hospital, Akershus University Hospital, Vestre Viken Hospital Trust, Vestfold Hospital Trust, and Østfold Hospital Trust) between 2004 and 2013. The remaining hospitals in the region have hospital-based imaging only.[16] The mobile radiography services cover 33 out of 75 municipalities in the region. More details on the demographics of the region are presented in Table 1.

**TABLE 1** Demographic description of travel distance, population density, nursing home beds and municipalities included in mobile radiography services

| Hospital trust | Mean Travel Distance to Hospital (km)[a] | Population Density (per km$^2$)[b] | Nursing Home Beds (*n*)[b] | Municipalities Included/Total Number of Municipalities (*n*) | Population Density in Included Area (per km$^2$) |
|---|---|---|---|---|---|
| Oslo University Hospital | 6 | 1 564 | 4444 | 1/1 | 1 564 |
| Vestfold Hospital Trust | 22 | 120 | 1767 | 12/12 | 120 |
| Akershus University Hospital | 25 | 117 | 3868 | 8/20 | 111 |
| Vestre Viken Hospital Trust | 19 | 34 | 1962 | 10/26 | 218 |
| Østfold Hospital Trust | 22 | 75 | 2059 | 2/17 | 204 |
| Telemark Hospital Trust | 20 | 13 | 1373 | 0/18 | - |
| Innlandet Hospital Trust | 53 | 7 | 3766 | 0/44 | - |
| Sørlandet Hospital Trust | 17 | 20 | 2218 | 0/28 | - |

[a]Data from hospitals.

[b]Numbers from Statistics Norway.

## 2.2 | Developing the decision model

A decision model was developed in TreeAge (TreeAge Pro 2017, R2.1. *TreeAge Software, Williamstown, MA; software available at http://www.treeage.com*) that included two service alternatives:

1. A mobile radiography service combined with hospital-based imaging
2. Hospital-based imaging alone

The alternatives in the model are presented in Figure 1. Due to the fact that mobile radiography services run only during the daytime on weekdays, nursing homes residents may have needed a hospital X-ray examination outside of this timeframe,[13,14] including, for example, falls that occur over the weekend or an acute situation at night that requires an X-ray examination. In areas with only hospital-based imaging, 10% to 20% of the residents are unable to be X-rayed because their state is too poor for transportation or there is a lack of personnel to accompany the resident to the hospital.[13,14,23] These residents were treated in the nursing home based on a clinical diagnosis alone.[13,14,23] If treatment was needed after the X-ray examination, treatment could be given in a nursing home or at hospital either as outpatient or as inpatient treatment.[12-14,23]

## 2.3 | Probabilities used in the decision model

Probabilities on whether residents were examined in a hospital or by a mobile radiography service was calculated through the nursing home residents' use of imaging services in four hospital trusts with a mobile radiography service in Southeast Norway in 2015 (Oslo, Akershus, Vestre Viken, and Vestfold).

Previous research indicates that 76% of the nursing home residents who had an X-ray examination needed treatment based on the results of the imaging.[13,14] When examined at the nursing home, 62% of the residents in need of treatment were treated there as well; 7.5% of residents examined at the nursing home were admitted to hospital.[12-14] When examined at the hospital, 68% of the residents in need of treatment were treated in a nursing home. The rest of the residents were treated in hospital, and, of these, 23% were admitted.[13,14,23] The probabilities are presented in Table 2. All probabilities are entered as beta distributions where appropriate.

## 2.4 | Costs used in the decision model

All residents in nursing homes need to be examined by a physician for a referral, and the regulated physician visit fee was used.[24] According to Hektoen,[11] this fee should be doubled in order to account for operating costs. For an X-ray examination in a hospital (cost per patient), the salary for the radiographer, the capital costs of equipment and facilities, and the operating costs were included for chest, hip, and pelvic examinations (Oslo University Hospital, unpubl. observ.). In the case of an X-ray examination in a nursing home, the labour of the radiographer, the transportation, the capital costs of equipment and vehicle, and the overhead costs were included for all types of general X-ray examinations.[25] According to earlier research, 50% to 88% of nursing home residents use an ambulance when transferred to a hospital.[13,14,23,26] Thus, it was assumed that 70% of the residents needed an ambulance transfer, and it was assumed that the rest of the residents used a taxi. The costs of the taxi transfers were calculated as the average km travelled multiplied by the cost per kilometre with a start fee.[27] Based on data from the eight hospital trusts in Southeast Norway, on average, the travel distance was 27.08 km between the nursing homes and hospitals. According to Lærum et al,[23] 75% of residents were in need of nursing home personnel to accompany them to the hospital. Thus, it was assumed that 25% of the residents were accompanied by an adult family member who used one workday to accompany the resident.[12,23,28]

The treatments for hip fractures and pneumonia were used to estimate the cost of inpatient hospital treatment through the Norwegian DRG (Diagnosis-related Group) codes.[29] These are assumed to be the most common treatments related to a hospitalization after an X-ray examination of nursing home residents.[5,7] The cost of outpatient treatment was calculated from the Norwegian DRG for outpatient treatment of pneumonia infections and minor fractures.[29] Moderate and mild pneumonia and several other minor conditions could be

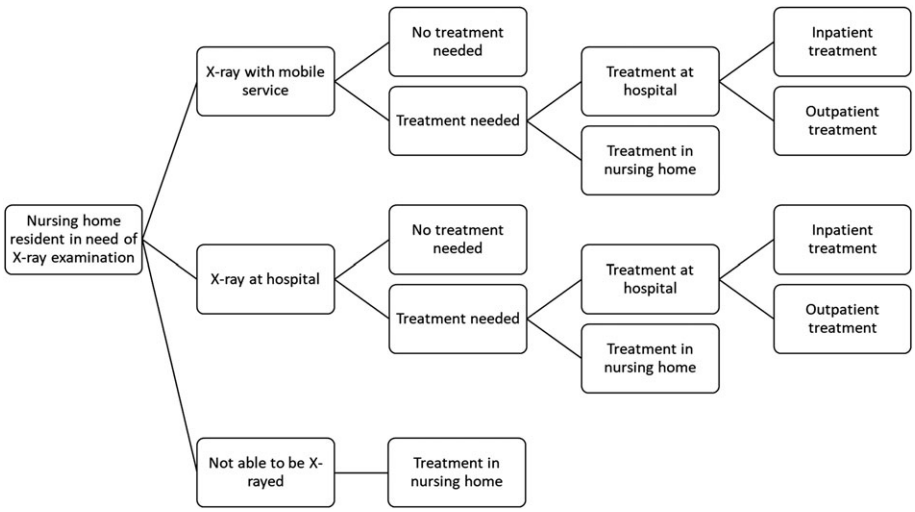


**FIGURE 1** An illustration of the developed decision model, with alternatives for examination and treatment

**TABLE 2** Table of transition probabilities used in the developed decision model, with mean, standard deviation (SD), and 95% confidence interval (CI) of the mean

| Transition Probabilities | Mean (SD) | 95% CI | Reference |
|---|---|---|---|
| No treatment needed after examination | 0.24 (0.03) | 0.237-0.241 | Lærum et al[13] and Vigeland et al[14] |
| With mobile radiography service | | | |
| To be examined with mobile radiography service | 0.8 (0.08) | 0.798-0.807 | Data from hospitals |
| To be examined at hospital | 0.2 (0.08) | 0.193-0.203 | Data from hospitals |
| Treatment given in nursing home | 0.62 (0.03) | 0.618-0.621 | Eklund et al[12] and Vigeland et al[14] |
| Inpatient treatment | 0.075 (0.003) | 0.0749-0.0752 | Lærum et al[13] and Vigeland et al[14] |
| With hospital-based imaging only | | | |
| To be examined | 0.835 (0.02) | 0.834-0.836 | Lærum et al[13] and Vigeland et al[14] |
| Treatment after hospital X-ray | | | |
| Treatment in nursing home | 0.68 | | Lærum et al[13] |
| Inpatient treatment | 0.23 (0.05) | 0.23-0.236 | Lærum et al,[13] Vigeland et al,[14] and Lærum et al[23] |

treated at a nursing home.[5,7] To estimate the cost of nursing home treatment, it was assumed that an average of 7 days of treatment and care with a multidisciplinary team was used.[11] The costs of services that would remain the same regardless of where the examination took place were omitted (eg, reporting costs and administrative handling of referrals). The costs are presented in Table 3. The costs are entered as gamma distributions in the model where appropriate.

All of the costs were based on the 2016 Norwegian kroner converted to the Euro (€) by using the 2016 average currency rate (9.2899).

### 2.5 | Statistical analyses

With TreeAge, in order to evaluate the impact of parameter uncertainty, probabilistic sensitivity analysis (PSA) was used.[30] SPSS (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.) was used for the descriptive statistics and paired-samples *t* test.

## 3 | RESULTS

The calculated cost per examined and treated resident with hospital-based imaging was on average €2790. The average cost per resident with the combination of mobile- and hospital-based services was €1946 (Table 4). This constitutes a 30% cost reduction per resident. Considering there were at least 7375 X-ray examinations for nursing home residents in Southeast Norway in 2015, this would amount to a total cost reduction of just above €6 224 000.

The illustration of the Monte Carlo probability distribution of the cost differences of the compared alternatives is shown in Figure 2. The alternative with the combined services gave a cost reduction in all 1000 runs compared to the hospital-based imaging alone. The cost reduction would most likely be €560 to €1 080. A paired-samples *t* test was used to further evaluate the difference in cost between the two alternatives. The cost reduction in the combined alternative was significant, with a mean cost reduction of €844 with a 95% confidence interval ranging from €837 to €851 (SD = 112.4), $P < 0.001$ (two-tailed).

## 4 | DISCUSSION

This cost analysis presents a cost comparison of two alternative options for radiography services, including hospital-based imaging alone and hospital-based and mobile radiography services combined. The analysis demonstrated that the combined mobile and hospital-

**TABLE 3** Cost items used in the analysis in 2016: Euros (€), with mean cost, standard deviation (SD), and 95% confidence interval (CI) of the mean

| Costs | Mean (SD) | 95% CI | Reference |
|---|---|---|---|
| Medical examination in nursing home | 66 | | Hektoen[11] and The Ministry of Health and Care Services[24] |
| Ambulance, one way | 650 | | VVHF[25] |
| Taxi one way[a] | 88.5 (8.8) | 88-89 | Vigeland et al,[14] and Statistics Norway[27] |
| Accompanying personnel – 1 day | 242 (2.4) | 242-242.3 | Hektoen[11] |
| Accompanying family member – 1 day | 215 | | Statistics Norway[28] |
| X-ray examination in nursing home | 144 | | VVHF[25] |
| X-ray examination in hospital | 100 (11) | 99.7-101 | [b] |
| Inpatient treatment | 6753 (1540) | 6649-6857 | The Norwegian Directorate of Health[29] |
| Outpatient treatment | 192 (22) | 191-194 | The Norwegian Directorate of Health[29] |
| 7 days of treatment in nursing home | 2219 (104) | 2212-2225 | Hektoen[11] |

[a]Average 3€/km charge. Mean start[27] fare of €5.

[b]Cost per patient (CPP) at Oslo University hospital, unpubl. observ.

**TABLE 4** Mean costs related to nursing home residents in need of X-ray examination and treatment with standard deviation (SD) and 95% confidence interval

| Alternatives | Mean € (SD) | 95% CI |
|---|---|---|
| With mobile radiography service | 1946 (139) | 1937-1954 |
| Without mobile radiography service | 2790 (138) | 2782-2799 |

Results after 1000 Monte Carlo simulation in the decision model with input from Tables 2 and 3.

based X-ray services provide a 30% cost reduction compared with hospital-based imaging alone. In addition, there is a possibility for an even higher cost reduction if the radiographer examines more than one patient at each nursing home visit. Randers[22] calculated that there would be a 50% cost reduction on the second examinations; however, to be able to perform more than one examination per visit requires planning from both the nursing home staff and the radiographer running the service.

## 4.1 | Quality of treatment and care

The effects of mobile radiography services were not evaluated in this study. However, earlier research has shown that mobile radiography services facilitate high-quality treatment and care.[16] According to Ranhoff and Linnsund,[6] nursing home residents would in most cases be better off treated in the nursing home. Providing adequate treatment in nursing homes would, in many cases, be easier when the diagnosis is supported by imaging.[19,23] Mobile radiography services would thus facilitate better treatment and care for residents unable to travel and may increase the quality of life for residents who no longer need to travel back and forth just for an X-ray examination.[6,12,14,23]

## 4.2 | Transfer and hospitalization

The cost reduction was mainly due to reduction in transportation and the number of hospitalizations. A transfer by an ambulance is costly (compared with a transfer of the X-ray equipment) both economically and in reference to the resident's health condition.[20,22] Previous research has calculated costs with mobile radiography services in relatively highly populated areas in Norway and Sweden, with a mean travel distance of 10 to 20 km.[20-22] This cost analysis included both highly and sparsely populated areas with a mean travel distance of 27 km. In areas where the travel distance to hospital is long, the population density is low. This may result in fewer examinations than expected with the mobile radiography service per day.[21] However, the cost reduction per examination and treatment would be high due to transportation costs, including the accompanying staff or family members.[21,22] Further, the strain on the residents may increase with time away from the nursing home.[23] Due to long travel distance to hospitals in rural areas, the transfer could cause residents to not be

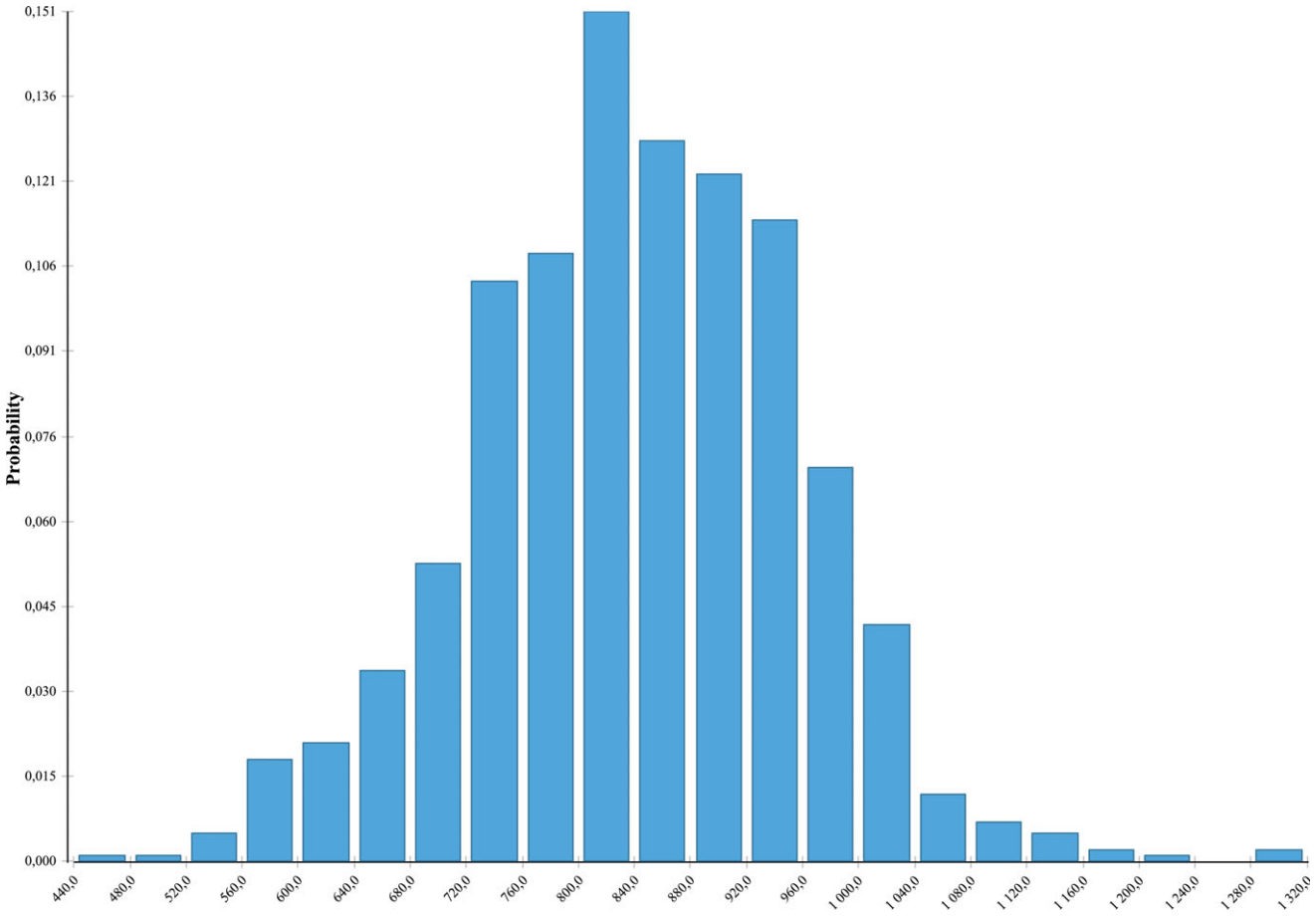


**FIGURE 2** Monte Carlo probability distribution

examined or the transfer itself could cause a hospitalization.[7,9,10,23] Treatment in the nursing home would be the best alternative for most residents because of their poor health and need for a calm and familiar environment.[6,14,16]

### 4.3 | Silos in health care

In Norway, the responsibility for health care services is divided between municipalities (primary health care, eg, nursing homes) and regional health authorities (specialist health care, eg, hospitals).[17] The different departments in the hospitals or municipalities are responsible for their own budget.[17] This may lead to a silo effect within the health care services. The investment costs are high for the imaging department when setting up a mobile radiography service. The change in service delivery leads to a cost reduction in other hospital departments and in the municipalities, due to reduction in transfers and hospitalizations.[16-19] Thus, the imaging department would not benefit from their investment. Such division may obstruct the introduction of a mobile radiography service.[19]

### 4.4 | Limitations in the current analysis

The decision model is based on as much real data and values as possible. However, when real data could not be found, assumptions were used. These assumptions could distort the actual cost difference between the two alternatives. In particular, the assumptions on costs of treatment and ambulance transportation do have a high influence on the result. Notwithstanding its limitations, this study provides evidence that mobile radiography reduces health care costs in Southeast Norway based on the best data available at the time.

### 4.5 | Implications for practice and further research

Telemedicine applications, such as mobile radiography services, provide a new way of organizing health care services. When introducing telemedicine services, it is important to assess the economic outcome of the new service.[31] This could contribute to a wider use of mobile radiography services, as it serves to provide knowledge needed for managers in health care to make decisions on the implementation of change in health care organizations. Further research is needed on the effects of this service in order to be able to perform a cost-effectiveness analysis. Further, other imaging modalities, such as computed tomography or ultrasound, could be mobilized in a similar manner. The benefits for the residents on staying in their familiar environment may be similar. Thus, cost analysis or cost-effectiveness analysis of mobilizing these modalities would be interesting in order to facilitate better resource allocation in health care in the future.

In conclusion, an introduction of a mobile radiography service in Southeast Norway contributes to a cost reduction per resident that is examined and treated by approximately 30%. Avoided transfers and hospitalizations contributed the most to the cost reduction.

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# Paper IV

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RESEARCH ARTICLE Open Access

# Managers' experience of success criteria and barriers to implementing mobile radiography services in nursing homes in Norway: a qualitative study

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## Abstract

**Background:** In order to meet the future challenges posed by ageing populations, new technology, telemedicine and a more personalized healthcare system are needed. Earlier research has shown mobile radiography services to be highly beneficial for nursing home residents in addition to being cost-effective. Despite the benefits, mobile radiography services are uncommon in Europe and Norway. The purpose of this study was to explore success criteria and barriers in the process of implementing mobile radiography services, from the point of view of the hospital and municipal managers.

**Methods:** Eleven semi-structured interviews were conducted with managers from five hospitals and six municipalities in Norway where mobile radiography services had been implemented. Core issues in the interview guide were barriers and facilitators in the different phases of implementation. The framework method for thematic analysis was used for analysing the data inductively in a research team.

**Results:** Five main categories were developed through the success criteria and barriers experienced by the participants: national health policy, regional and municipal policy and conditions, inter-organizational implementation projects, experienced outcome, and professional skills and personal characteristics. The categories were allocated into three higher-order classifications: macro, meso and micro levels. The main barriers experienced by the managers were financial, procedural and structural. In particular, the reimbursement system, lack of management across healthcare levels and the lack of compatible information systems acted as barriers. The main facilitators were external funding, enthusiastic individuals in the organizations and good collaboration between hospitals and municipalities.

**Conclusions:** The managers experienced financial, structural and procedural barriers. The main success criteria in the process were external funding, and the support and engagement from the individuals in the organizations. This commitment was mainly facilitated by the intuitive appeal of mobile radiography. Changes in healthcare management and in the financial system might facilitate services across healthcare levels. In addition, compatible information systems across healthcare levels are needed in order to facilitate the use of new technology and mobile services.

**Keywords:** Mobile radiography service, Barriers, Facilitators, Implementation, Coordination, Nursing homes, Mobile health units, Radiography, Telemedicine

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## Background

The use of telemedicine, new technology and a personalized healthcare system are some of the measures used to meet the challenges of ageing populations in Europe [1]. One of the concerns is an increase in the number of persons living in nursing homes [2]. More than 80 % of nursing home residents have dementia and many are living with several comorbidities [3]. Thus, nursing home residents need highly coordinated and integrated services [4]. In addition, there is a high incidence of infections and injury due to falls [5–7]. All these elements increase the need for specialized healthcare services, including imaging service, among nursing home residents compared to the rest of the population [3, 7]. According to Wang et al. [7] about 72 % of nursing home residents visiting an emergency department need an imaging test and 85 % of these tests are conventional x-ray examinations. Today, radiological services for nursing home residents are usually provided at a hospital or in an emergency room. New surroundings such as an x-ray department may increase the risk of falling and/or developing anxiety or delirium [7–10]. Mobile radiography as a telemedicine service allows residents to stay in the nursing home, which may reduce these kinds of complication and avoiding admission to hospital [11, 12]. Recent research suggests that mobile radiography services in nursing homes are psychologically preferable for the residents and that these services are also economically preferable [12, 13]. Despite these advantages, mobile radiography services are not common in Europe. In Norway, only five out of twenty public hospital trusts and one private hospital are in the process of implementing or have implemented mobile radiography services through implementation projects [12]. Oxman et al. [14] list a number of barriers to coordination or integration in healthcare systems, based on Nolte and McKee [15]. These barriers are structural, financial, legal, procedural, professional, conflicting views, organizational self-interest, organizational turbulence and introduction of a competitive environment [16]. To overcome these barriers and succeed in implementing an innovation or change, both organizations and individual professionals need to have a common understanding of the problem, and agree that change is needed [14, 16]. For an easier implementation process the innovation needs to be considered to have a low financial risk. In addition, the innovation or change needs to be considered useful, compatible with existing values, easy to use and to have a large number of supporters in the organizations [14, 16]. During the process of implementation, evaluation of the impact of the innovation on the organization is important. In addition, this impact must be communicated to the individuals in the organization [16]. Further, adequate finances for training and for building the structure are important during implementation in order to succeed.

This study forms part of a larger research project on mobile radiography services for nursing home residents in Norway. The objective of this study was to identify success criteria and barriers in the process of implementing mobile radiography services, from the hospital and municipal manager's point of view. This knowledge could make it easier for other hospitals and municipalities to implement mobile radiography services and similar services.

Accordingly, this study addressed the following research questions:

- What do managers in municipalities and hospitals experience as success criteria in the implementation of mobile radiography services?
- What do managers in municipalities and hospitals experience as barriers to implementing mobile radiography services?

## Method

This is a qualitative study based on semi-structured interviews. Before describing the methods in detail, the study context is presented.

### Context: The Norwegian healthcare system

The Norwegian healthcare system is mainly a public system based on general taxation. The system is managed politically at the ministry and municipality levels [17]. The municipalities mainly provide primary healthcare services including general practitioner services (GPs), preventive care, nursing homes and rehabilitation [17]. Specialized healthcare, including imaging services is mostly provided by hospital trusts, led by the Ministry of Health and Care Services through regional health authorities [17]. The Norwegian healthcare system struggles with fragmentation challenges due to the lack of central responsibility for coordination across services [14]. To meet these challenges, the Coordination Reform was implemented in Norway in 2012. The aims of the Coordination Reform were to improve public health and the quality of health services in a sustainable manner [18]. In the process of implementing the Coordination Reform, municipalities could apply for funding for collaborative projects that aimed to transfer tasks from the hospitals to the municipalities [19]. In general, health and care services are funded by a combination of block grants, activity-based financing and patient fees [18].

### Participants and local context

Semi-structured interviews were conducted with eleven mangers from five hospitals and six municipalities,

which is an acceptable sample size for studies that utilize a qualitative approach [20].

The participants in this study were recruited from municipalities and hospitals where mobile radiography services had been implemented during the last decade. Using volunteer sampling [21], participants from different healthcare levels and management levels were included. All participants volunteered by contacting researcher EK after an invitation was sent to the municipalities and hospitals defining the inclusion criterion. The inclusion criterion was: managers who had been involved in the implementation of mobile radiography services. In municipalities this included either administrators of health services, or managers of nursing homes. In hospitals this included either departmental (x-ray department) or directorial (higher order) managers. Further information about the participants and their context are presented in Table 1. Participants were provided with an information letter and consent form via e-mail when volunteering. The signed consent form was collected by EK before starting the interview.

All mobile radiography services that were included were implemented through collaborative implementation projects with one hospital and several municipalities. The number of municipalities covered by the services varied from 2 to 10. In all areas, health cooperation committees between municipalities were in place prior to the implementation of mobile radiography services. Three areas (B, D and E) had completed the mobile radiography service project, and mobile radiography had become part of the regular imaging service. The rest of the projects were in their last year and were in the process of including mobile radiography as part of the regular service.

### Data collection

The semi-structured approach was chosen to ensure that the same topics were discussed with all the participants whilst allowing relevant topics to be explored when they arose [20]. An interview guide with open-ended questions was developed for the core issues to be discussed openly. Core issues included barriers and facilitators for the decision to implement mobile radiography services in the implementation process and in daily practice. The interview guide is available in Additional file 1: Table S1. The interviews were conducted from February to May 2016, and were carried out at a place of the participants' choice, all at the participant's work place. A Zoom H1 Handy Recorder was used to record the interviews. EK interviewed all the participants and researcher AMM was present at three of the interviews (interviews one, four and seven). The interviews lasted on average 40. 9 min (17.3–53.2 min). In order to reach consensus [20], at the end of each interview, EK summarized the participant's statements of the main subjects in the interview.

The Norwegian Centre for Research Data approved the handling and storage of personal information in this study. The Norwegian Centre for Research Data considered approval of this study by the Ethical Committee to be unnecessary.

### Analysis

The analysis took place in a team of four members (the authors) and used the framework method for thematic

**Table 1** Information about the participants and the local context

| Area | Number of municipalities included in the service | Population in the area [31] | Size of the area ($km^2$) [32] | Participant | Management position | Experience as a manager[a] |
|---|---|---|---|---|---|---|
| A | 10 | 369,714 | 1823 | 1 | Hospital administrator[b] | Long |
| | | | | 2 | Municipal administrator[c] | Long |
| B | 2 | 135,248 | 694 | 3 | Municipal administrator[c] | Long |
| | | | | 10 | Manager of x-ray department[e] | Long |
| C | 10 | 230,899 | 2174 | 4 | Manager of nursing home[d] | Long |
| | | | | 7 | Manager of x-ray department[e] | Long |
| D | 8 | 212,109 | 2004 | 5 | Manager of nursing home[d] | Long |
| | | | | 6 | Manager of nursing home[d] | Short |
| | | | | 11 | Manager of x-ray department[d] | Long |
| E | 5 | 315,462 | 1402 | 8 | Municipal administrator[c] | Long |
| | | | | 9 | Project manager at the hospital[f] | Just for the project |

[a]Short experience is defined as less the two years, long experience is defined as more than two years
Exact time in management position was not part of the data collection
[b]Managers working in administrative positions outside the x-ray department
[c]Managers working in administrative positions in municipal administration
[d]Managers working in a nursing home department with personnel management
[e]Managers working in an x-ray department with personnel management
[f]Project manager for the local mobile x-ray service project

analysis, as described by Ritchie [22]. The use of the framework method is a well-established approach in thematic analysis of semi-structured interviews [22]. The analysis process of the framework method in a team has seven stages, as described by Gale et al. [23]. The way in which these stages were applied in the study is presented in Table 2.

### Trustworthiness

As recommended by Yardley [24] the initial analysis was determined through discussions and consensus in the team performing the analysis. Transparency and coherence are supported by the audit trail in the framework method [23]. This is ideally evident in the close correspondence between the presented data and the claims made. Impact and importance were tested by presenting this study at two open research seminars. Feedback from these seminars was used to refine the analysis.

## Results

Eighty key dimensions were identified in the matrices developed in QSR International's NVivo Pro version 11 software (NVivo) (see Additional file 1: Table S3), these were allocated into five categories: national health policy, regional and municipal policy and conditions, inter-organizational implementation projects (including five sub categories), experienced outcome, and professional skill and personal characteristics. These main categories were allocated into three higher order classifications: macro, meso and micro levels. The classifications, categories and sub-categories are presented in Fig. 1.

The category inter-organizational implementation projects at meso level was considered a core category where the subcategories describe a variety of factors affecting the actual implementation process. As the respondents act on the meso level, the data are more detailed in this level. First the macro and micro levels will be presented with barriers and facilitators affecting the internal processes and measures taken in the meso level.

### Macro level

#### *National health policy*

The Norwegian healthcare system influenced the implementation of mobile radiography services in different ways, both as a barrier and a facilitator. Financial barriers and facilitators were most prominent. Managers experienced that the reimbursement system for specialized healthcare services was made for services provided in hospitals. The fee-for-service reimbursement for an x-ray examination was identical whether the service was provided in a hospital or in a nursing home. This was considered unfair by both hospital and municipal managers, because the resources used by the x-ray department were significantly higher per examination with the mobile service. Thus, the activity-based part of the funding was a barrier for mobile services. One hospital administrator said:

> "*The reimbursement system was not made for mobile services… It was made for an old-fashioned system in which things happen within four walls, such as in hospitals*".

The participants considered that the Coordination Reform facilitated mobile services by defining the principles for cooperation between hospitals and municipalities through contracts. In addition, the Reform allocated funding for projects. This funding

**Table 2** The seven stages of the analysis process used in this study based on Gale et al. [23]

| Stage | Who and how |
|---|---|
| Transcription | EK transcribed the recordings verbatim |
| Familiarization | All researchers familiarized themselves with the data by reading through the transcripts |
| Coding | Two researchers coded openly three transcripts |
| Developing the working analytical framework | All 4 researchers met to discuss and agree on a set of codes grouped into categories in a working analytical framework. In addition, the researchers met to engage in reflexivity discussions. Using this analytical framework and further open coding, two researchers coded the next four transcripts. Then, after a new discussion, the team revised and refined the framework. This process was repeated until all transcripts were coded. Finally a final thematic framework was agreed upon. The framework consisted of six categories with 4–10 codes each. These are available in Additional file 1 Table A2. |
| Applying the analytical framework | EK indexed all transcripts using QSR International's NVivo Pro version 11 software (NVivo). |
| Charting the data into the framework matrix | EK charted the data into 33 matrices consisting of cases in the rows and codes in the columns using NVivo. |
| Interpreting the data | Thematic analysis for descriptive purposes was performed by EK supported by AMM, as described by Ritchie [24]. Elements were detected in the data summaries in the matrices. These elements were sorted according to underlying dimensions and key dimensions were identified. Then categories and higher order classifications were identified. All the researchers met to discuss findings and to reach a consensus. |

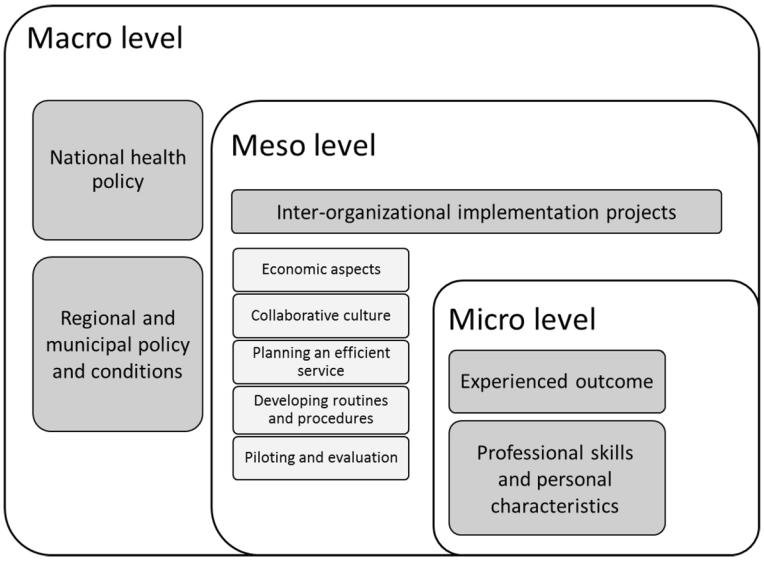


**Fig. 1** Classifications, categories and sub-categories from inductive data analysis. The 3 higher-order classifications are represented by the white boxes. Categories are represented by dark grey boxes within each level. In the meso level there are sub-categories represented by light grey boxes

facilitated projects. However, when this funding was no longer available, the participants experienced this as a barrier for new mobile radiography services. One municipal administrator said:

> "*The funding facilitated it [mobile radiography services]*".

### Regional and municipal policy and conditions

Several barriers were identified at the regional and municipal levels. One barrier identified was organizational changes. In large reorganizations there was no time or money for innovation. In addition, both financial and structural barriers were identified. Mobile radiography represented a new way of cooperation and coordination across healthcare levels. Mobile radiography services are not part of ordinary primary care, and general radiography services are not usually mobile. Thus, municipalities or hospitals are not legally obligated to provide these services. This makes a mobile radiography service a different kind of healthcare service, and a new way of organizing and financing services. Thus, in municipalities, support from local politicians was important for money to be allocated in the budget. The process of gaining political support was time consuming and acted as a barrier. One nursing home manager said:

> *"This must also be supported at the chief municipal executive level. And when councilors change jobs or when new municipal councils come into power and so on, there is a risk that these kind of projects disappear, because they have such weird financing".*

### Micro level

#### *Experienced outcome*

Most staff and managers had a positive attitude towards mobile radiography services. Participants said that a few physicians in nursing homes were sceptical to mobile radiography services because they considered that a clinical diagnosis was sufficient for these residents. So they regarded imaging tests as unnecessary. Most participants experienced that staff and managers considered imaging tests to be an important diagnostic tool for nursing home physicians, and that avoiding transfer to hospital was important for the residents. Mobile radiography was considered to increase the quality of the service for residents and family members. Also, the general quality of care in the nursing home was considered to be improved, because personnel did not need to spend time arranging for volunteers or family members to accompany residents to hospital for an x-ray, or to accompany residents themselves. One nursing home manager said:

> *"So here we are working with placing the patient in the centre, and thinking holistically about the patient. And this [mobile radiography] is very patient friendly. And I think that's an important argument … It [mobile radiography] saves us a lot of frustration in relation to transportation, waiting for an ambulance, and finding someone to accompany the patient. It is*

*much easier when we can just call and they say we're coming rather than using family members or the volunteer centre".*

#### *Professional skills and personal characteristics*

The participants experienced that key personnel initiated, motivated or facilitated the service. These projects were mostly initiated by one person within the hospital or municipality. Without these enthusiasts the service may not have been implemented. One municipal manager said:

*"We had a doctor who was enthusiastic, an elderly physician at the time, who was really into this [mobile radiography] …, she was very motivated and tried to persuade me to say that we had to have this".*

In the implementation process, the radiographers running the services had an important role in marketing and establishing good relations with the nursing home staff. One nursing home manager said:

*"Those who come here are very nice, very helpful and very welcoming. It mean a lot that those who provide the treatment [mobile radiography] also think that this is a great service".*

### Meso level

#### *Collaborative implementation projects*

The mobile radiography service needed to be defined and set up in cooperation between the hospital and the surrounding municipalities. This presented both administrative and practical challenges such as referral routines, communication, parking and adapting the vehicle. All areas established implementation projects led by the hospital, with managers from both the hospital and the collaborating municipalities. These projects involved deciding about purchases, organizing the service, marketing, and evaluating the service. One municipal administrator said:

*"When the decision was made, when we decided, yes we will have a project, and we have the money, then we had to ensure that all the structures were in place first. So we established a project with a steering committee and project group".*

#### *Economic aspects*

Because the idea to implement mobile radiography services mostly came from one enthusiast, getting support from the top management in all the organizations was the greatest challenge. This support was necessary in order for money to be allocated in the budget in the organizations. One municipal administrator said:

*"Perhaps the challenge with this kind of project was that it came from an enthusiast. It lacked anchorage in top management. It was a good project and it was nice to talk about it. But the lack of anchorage in top management made the funding a challenge".*

Because of the financial barriers at the macro level, most managers in hospitals and x-ray departments were not willing to invest in equipment, a vehicle and staff for the mobile service. The risk was considered high, because this was a new type of service that there was limited knowledge about and little experience of its use and efficiency. To overcome the financial barriers most of the projects applied for external funding and used contracts between the hospital and municipalities, as recommended by the Coordination Reform. This provided financial security and divided the costs between all the parties. The most common financial model used was one where the hospital covered 50% of the costs and the participating municipalities covered the other half of the costs. The division among the municipalities was usually calculated based on the number of inhabitants in the municipality. One hospital administrator said:

*"For the part that was not externally funded, we agreed on a 50-50 economic model. The municipality covered half of the costs and the hospital trust covered the other half… This was really important for the hospital trust".*

However, developing and agreeing on contracts took a lot of resources and slowed down the implementation. In one area, the bureaucratic process of contracts was the main reason for not involving the municipalities financially. The manager from the x-ray department in this area said:

"*If we had contracts with several municipalities, the contracts would need to be revised and kept up to date. We were not actually talking about much money, so the disadvantages of the bureaucracy outweighed the benefits".*

#### *Collaborative culture*

The participants from the municipalities experienced the x-ray department managers as respectful and grateful. All project members were highly committed and engaged in the project. Participants described a good collaborative culture within the project groups.

They all wanted to increase the quality of the services for residents. Thus, they kept working despite the barriers. One nursing home manager said:

*"You must have enthusiasm all the way, if not you will fail".*

In the area where the hospital covered all costs, co-operation was also important, not in order to gain support from the management in the municipalities, but to understand the needs of the nursing homes. The x-ray department manager in this area said:

*"It was very important to involve them [the nursing home staff]. They could point out their needs and the importance of having x-ray as a diagnostic tool in the nursing home. I think that was very important".*

#### *Planning an efficient service*

Another important aspect in the implementation project was to tailor the service to the local demographics to ensure efficiency. Travel distances and traffic in the area were considered when planning the services. The population size needed for the service to be cost-effective was perceived differently in the different areas. In one area, two municipalities with just over 130,000 inhabitants was considered sufficient. However in another area, more than 300,000 inhabitants was considered to be necessary for the project to be cost-effective. However, all participants agreed that the service needed to be in an urban area. One hospital administrator said:

*"This is a typical example of mobile services being cost-effective in densely populated areas, quite the opposite of what people think".*

To keep the service running all year with an appropriate response time, a group of radiographers rotating within the service was needed (2–7 in these projects). Keeping the service up and running was important for the quality and reputation of the service. If the services failed to arrive on time, the nursing homes would send residents to a hospital instead. In all areas the service was available on weekdays, daytime only. It was considered important that the examinations were done within the next day, because most examinations were semi-acute. One x-ray department manager said:

*"We've said that these are semi-acute examinations. Our aim is to carry out the examination within the course of the next day, but it is not guaranteed, it's one of those semi-acute services".*

To initiate the required treatment, the radiologists were required to report the examination on the same day and call the nursing home if there were any findings that required immediate action. If the nursing home physician was present when the examination was carried out, the images could be viewed on site as well. In addition, the radiographers communicated with the physician directly, or a radiologist by phone, if they suspected critical findings (e.g. fractures) in the images during the examination. One municipal administrator said:

*"Yes, if you are at the bedside you get to see the image and that's ok… we need the results quickly, we get the results mostly the same day. She [the radiographer] looks at the images there and then as well, and lets us know if there is anything special".*

It was planned to send referrals and reports electronically between the nursing homes and the hospitals. In addition, wireless transfer of images from the mobile unit to the hospital was planned in order to reduce reporting time. However, none of the projects had come so far. They experienced a combination of legal and procedural barriers for wireless image transfer. To avoid these barrier they used paper-based referrals and reports. In addition, they sat up connections for image transfer at places that were easily accessible outdoors in different hospitals, to transfer images via memory stick or cable. One x-ray department manager said:

*"Transfer of images was also a challenge in other projects. We have not yet come so far either. So we are still working on this, and we have the money, but we haven't got the solution up and running yet… Now we use a memory stick".*

#### *Developing routines and procedures together*

The participants described collaboration in development of a new service, routines and clinical procedures as important. In one area, routines were not discussed with the nursing home physicians prior to piloting the service. This made the implementation a bit chaotic. There were misunderstandings about referral routines and what types of examination it was possible to do in the nursing home. In the other areas, the target population and what types of x-ray examination to offer were discussed in the implementation projects. In addition, what kind of assistance the radiographers needed at the nursing home, and routines for referral, bookings and communication, were discussed. One x-ray department manager said:

*"They [nursing home physicians and nurses] were involved in defining the service and talked about their needs in relation to the type of examinations they envisioned, how cooperation with the radiographer should be in the nursing home and with our radiologists here in relation to the results when we did not have wireless image transfer".*

#### *Piloting and evaluating the service*

After the period of planning and getting the equipment and a vehicle in place, the projects started a pilot where just a few nursing homes or municipalities were included. This made it possible to test equipment, to evaluate the facilities in the nursing homes, and for the radiographers to learn how to plan the day efficiently and gain experience in working alone in a mobile service. The x-ray equipment needed to fit safely in the vehicle, and the vehicle needed to be maintained. Further, the x-ray equipment needed to be designed for transportation into and within the nursing home. In addition, there was a need for sufficient power supply in close proximity to the residents' rooms. One nursing home manager said:

*"So there was talk of testing to be able to deploy this [mobile radiography services] in a sensible way. We tested it in two municipalities first".*

The pilot was also used for marketing. It was vital to make the service known to the nurses, physicians and managers, and to build networks. It was important to give information to the physicians who were the referrers and the nurses who were the ones who would contact the physician for a medical examination. Otherwise, no-one would use the service. One radiographer was responsible for visiting all the nursing homes to present the service and the new routines. In addition, the service was publicized in the newspapers. One x-ray department manager said:

*"We thought that it was important to have one designated person in the service who would drive around and establish contact with the nursing homes. It was important to have continuous dialogue, to get them to use us [the mobile radiography service]".*

The participants experienced evaluation during the pilot as important. The projects used feedback and surveys from physicians, nursing home staff and radiographers in their evaluation. In addition, statistics were discussed in the project meetings as a management tool. This would help to increase the use of the service and improve the quality. One x-ray municipal administrator said:

*"We received regular reports from the project manager, showing how much the service was used. This was a good parameter for asking questions in our own organization: Why are we not using mobile radiography? And we could compare ourselves with others. This has been a good tool".*

In summary, the barriers at the macro level were identified as the national reimbursement system, and large organizational changes. At the meso level, the main barriers identified were gaining support from the top management to get resources for the project with the process of making contracts, lack of management across healthcare levels, lack of electronic communication and wireless image transfer. In order to overcome these barriers, the implementation projects used different measures such as external funding and contracts, piloting, collaboration and manual communication procedures.

## Discussion

Although there were significant barriers to implementing mobile radiography services, facilitators such as external funding and engaged individuals contributed to overcoming them. The implementation projects adopted different measures to overcome barriers. Although the measures taken were not always ideal, pragmatic solutions were found through piloting and cooperation. The measures taken to overcome barriers in these projects seem to be consistent with earlier research [14, 16] and can thus be transferable to other contexts and technologies. A model of the main barriers and success criteria are presented in Fig. 2.

### Barriers

The barriers encountered were mainly financial, but also structural and procedural. When implementing mobile radiography services, society, municipalities and the hospital may save money because of fewer hospitalizations and less ambulance transport for nursing home residents [12, 13]. However, local managers have a limited overview of the total costs involved in the process. The decision to introduce mobile radiography services is made in the x-ray department where, for example, the reduction in hospitalizations is not visible in the department budget. Thus the economic burden of investment in a vehicle and equipment, as well as engaging new personnel is not offset by the reimbursement system and there is a reluctance to implement mobile radiography services. In order to facilitate telemedicine services, the reimbursement system should have separate telemedicine/mobile codes, with adapted reimbursement as

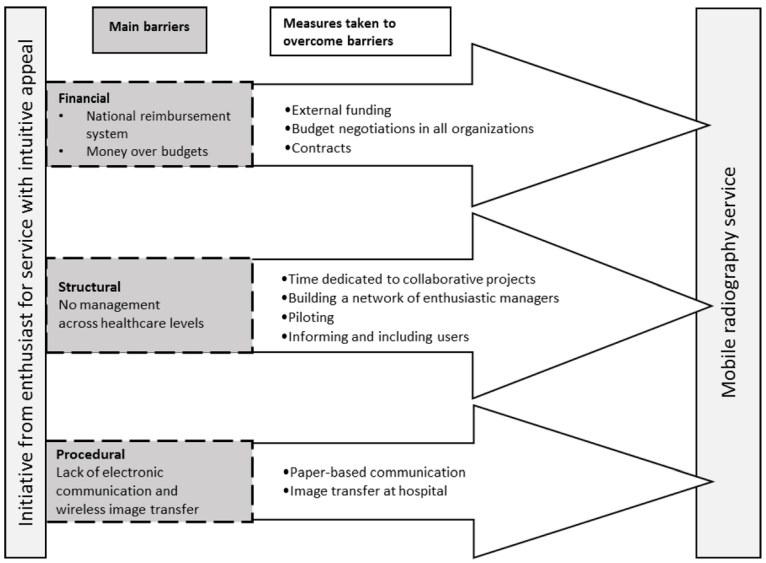


**Fig. 2** Model of main barriers and measures taken to implement mobile radiography services successfully. The box on the left represents the start of the projects. The dark grey boxes represent the barriers encountered in the implementation. The large arrows represent the measures taken in the projects in order to implement a mobile radiography service

discussed by Kidholm et al. [25]. This could contribute substantially to increasing the number of mobile or telemedicine services. Most of the collaboration projects in this study applied for external funding. External funding was considered to be fundamental to implementation. In the absence of such funding, improvement of the reimbursement system becomes even more important.

Large organizational changes reduce the available time and resources for innovation as well as creating organizational turbulence [14, 16]. In one of the areas included in this study, a large reorganization occurred during the implementation process. The managers used much of their time and resources on reorganization of staff and assignments, leading to the non-prioritizing of innovation and a barrier to innovative processes [14].

Lack of common information systems makes electronic referrals and reporting impossible. Paper-based routines may increase waiting and reporting time. In addition, wireless image transfer was impossible to use efficiently because of the unacceptable transfer time of 45 min per image. Within 45 min the radiographer would mostly be able to return to the hospital for image transfer. Therefore image transfer now takes place in the hospital at the end of the day. The participants were frustrated by the difficulties in setting up electronic communication and wireless image transfer. However, this technical barrier may soon be resolved by infrastructural evolution. Such projects highlight the need for solutions for transfer of referrals and images, and may thereby urge its technological development; progress that could also be useful for other types of mobile services.

After piloting in several areas and countries, other areas should be able to learn from these full scheme pilots, and implement the services more easily. However, experience and knowledge from the pilot schemes is not easily available. Only a few projects have published research from the implementations [9, 11, 26–29], whilst others have written reports, primarily for internal use. In order to facilitate mobile radiography and other mobile services in other areas, knowledge needs to be communicated both nationally and internationally.

### Success criteria

Mobile radiography was considered a financially high-risk innovation by management in hospitals and municipalities, therefore, increasing financial security was an important factor. The review of Greenhalgh et al. [16] indicate that innovations that are considered to be high risk are difficult to implement. All but one area applied for external funding and used contract between the involved parties, facilitated by the Coordination Reform [18, 19]. The use of contract to divide expenses between municipalities and the x-ray department, resulted in long and complicated processes in all included organizations in an effort to increase financial security. This was particularly the case when a large number of parties were involved. However, one hospital found the resources to independently finance mobile radiography services. This avoided the difficult process of achieving agreement with all the participating municipalities. This would appear to

be an easier and more efficient way to implement services across healthcare levels.

The establishment of a collaborative implementation project between the hospital and the municipalities was an important facilitator. According to Greenhalgh et al. [16], multidisciplinary project teams working semi-autonomously are associated with the successful implementation of innovations. The fact that the managers in the group met each other with respect and understanding made implementation easier. In all areas the managers were able to visualize the benefits of mobile radiography services for residents, staff and the healthcare service. Mobile radiography services seem to be compatible with the existing values in the organizations involved. This may have helped to create a good collaborative culture within the projects. Greenhalgh et al. [16] stated in their review that agreement about the need for change, and compatibility with existing goals and values in the organization, make the implementation process easier. With such shared understanding and engagement most of the projects developed local procedures and routines in collaboration. Earlier research has shown that adjusting to the local context is an important criteria in success [16].

One important facilitator made by the project groups was networking. Networks can be used for communication and setting up collaboration [16]. The project groups connected managers from municipalities with managers from the x-ray department. However, the use of the group members' existing networks in their own organizations was just as important. Through these networks, information and feedback between the municipalities and the hospital was conveyed. As shown in earlier research, these networks could help to create a shared understanding of the problem and agreement regarding the best way to organize the service [14, 16].

Piloting made it possible to adapt mobile radiography services to the local context. Piloting and adapting the services are important facilitators to success in an implementation process [14, 16]. During the piloting, the mobile radiography services were monitored and evaluated. In addition, the implications and changes made were communicated to the users in meetings. In the review of Greenhalgh et al. [16] evaluating changes, and keeping individuals in the organizations informed of changes was indicated to facilitate implementation, as involved parties experience an involvement in the process. [16].

Mobile radiography seems to be easily adopted by the users. Generally nursing home and x-ray department personnel thought that transporting residents to hospital for an x-ray was unacceptable/unethical in relation to the negative consequences for the residents. Thus, they shared the impression that mobile radiography services were useful and in the best interests of the residents. This attitude facilitates implementation. Earlier research has shown that a shared understanding of the situation and the need for change makes the individuals adopt changes more easily [14, 16]. To facilitate individual adoption, the projects used meetings, brochures and presentations to educate users about areas of application, benefits for residents, staff and society, and to introduce new routines and procedures.

### Limitations of the study

In this study, recruitment was based on the organizations finding a volunteer to represent them in the interview. To ensure rich data on implementation of mobile radiography services it was important to interview subjects who were included in an implementation project, in accordance with sampling strategies described by Creswell [30]. The participants were all recruited from organizations that were on the way to or had succeeded in implementing mobile radiography services. Thus the sampling may have led to a bias towards participants with a positive experience of mobile radiography projects. However, organizations which have not succeeded in implementing these services in Norway are not known to the authors. In addition, participants were recruited from only a few Norwegian municipalities. Thus, transferability may be difficult in other situations, although, rich, thick descriptions of the setting and participants would enable readers to determine transferability [30]. The results are based on participants' self-reported data, and no attempts have been made to verify their statements independently.

### Implications for practice

When planning implementation of mobile or telemedicine services, it is important to consider the possibility of the hospitals financing the services. To motivate the hospital management to take responsibility for financing, changes in the macro level seem to be necessary. Developing the reimbursement system or earmarking funds seems appropriate. Further, the healthcare system need managers with responsibility across levels in order to break down boundaries between primary and specialized healthcare. Compatible communication systems are important to increase efficacy when services cross healthcare levels. Thus, regional health authorities should facilitate compatible information systems.

If these changes were made at the macro level, it would be easier for new projects to focus on adaption of the services within the local context, rather than financial contracts. Further, another comprehensive pilot project would be unnecessary at least in the western world. Sufficient evidence on patient safety and utility of mobile radiography services has been established [12, 13]. However, small implementation projects to adapt the services

to the local context would help to ensure an appropriate response time, suitable routines and functioning.

### Further research

Further research is needed to explore barriers and success criteria of mobile services in other contexts and for other technologies. In addition, it would be relevant to evaluate the impact of financial barriers separately, as this seems to be the greatest obstruction. Further, evaluating cost-effectiveness of mobile radiography services in more sparsely populated areas of Norway and in other countries would be important in order to be able to recommend a wider implementation of mobile radiography services.

## Conclusion

This study set out to explore managers' experience of success criteria and barriers to implementing mobile radiography services. The result indicate that financial barriers caused by the financial system were most prominent, along with structural and procedural barriers. In addition to external funding, the main success criteria in the process was the support, engagement and hard work of individuals in the organizations who collaborated in these projects. This commitment was mainly facilitated by the intuitive appeal of mobile radiography services. In order to facilitate more mobile radiography services, or similar services in Norway and other countries, barriers need to be reduced, these include changes in the reimbursement system, or the allocation of earmarked funds. Further, there is a need for compatible information systems and managers with responsibility across healthcare levels.

## Additional file

**Additional file 1:** Includes the interview guide, analytical framework and identified key dimensions included in categories and higher-order classifications. **Table S1.** Interview guide, **Table S2.** Analytical framework with categories and codes and **Table S3.** Key dimensions, categories and classifications. (DOCX 19 kb)

#### Abbreviations

GP: General practitioner

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#### Availability of data and materials

The datasets generated and analysed during the current study are not publicly available due to participant anonymity issues, but are available from the corresponding author on reasonable request.

#### Authors' contributions

All authors participated in the planning of this study and analysis of the data. EK and AMM conducted the interviews. EK wrote the main parts of the manuscript. All authors read and approved the final manuscript.

#### Ethics approval and consent to participate

Ethics approval was not applicable in this study. The Norwegian Centre for Research Data approved the treatment of personal information – project reference 45,739. All participants gave written consent to participate in the study.

#### Competing interests

The authors declare that they have no competing interests.

## Publisher's Note



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**Contents - Additional file**



Table A1: Interview guide

| **Core questions** | **Major prompts** |
|---|---|
| First, could you please to tell me about the process of deciding to introduce mobile x-ray services?<br><br>How do you consider the decision process now in hindsight? | • Who took part in the decision-making?<br>• Which role did you take in this process?<br>• Which topics were discuss in this process?<br><br>• What complicated the decision?<br>• What made the decision process easier? |
| How did the introduction om mobile radiography services proceed? | • What complicated the introduction?<br>• What made the introduction easier? |
| How is the mobile radiography service today? | • What are the challenges?<br>• What facilitates continuation of mobile radiography services? |

Table A2: Analytical framework with categories and codes.

| **1 Background** | |
|---|---|
| 1.1 | Details on the participant |
| 1.2 | Work place |
| 1.3 | Existing cooperation groups |
| 1.4 | Status of the project to day |
| 1.5 | Area covered by the service |
| 1.6 | Financial model |
| **2 Frameworks and external factors** | |
| 2.1 | Demographical aspects |
| 2.2 | Financial aspects nationally |
| 2.3 | Law |
| 2.4 | Organisational framework of the health care services |
| 2.5 | Political anchoring |
| 2.6 | Funding |
| **3 Knowledge on mobile radiography, development and innovation** | |
| 3.1 | Experience from mobile radiography and other cooperation projects. |
| 3.2 | Research and documentation |
| 3.3 | Development of technology and the mobile radiography service |
| 3.4 | Attitude towards the service |
| 3.5 | Patient groups and clinical conditions |

| | |
|---|---|
| 3.6 | Quality and outcome |
| **4 Collaboration** | |
| 4.1 | User involvement |
| 4.2 | Information and communication |
| 4.3 | Local anchoring |
| 4.4 | Marketing |
| 4.5 | Cooperating and cooperation culture |
| 4.6 | Contracts |
| 4.7 | The understanding of the specialist health care service |
| **5 Organising mobile radiography services** | |
| 5.1 | Responsibility, roles and ownership |
| 5.2 | Routines and procedures |
| 5.3 | Proportioning the service to the demographics |
| 5.4 | Practical and ICT challenges |
| 5.5 | Project and piloting |
| 5.6 | Operational stability |
| 5.7 | Process and bureaucracy |
| 5.8 | Enthusiasts and key persons |
| 5.9 | Interest and motivation |
| 5.10 | Personal skills |
| **6 Economy** | |
| 6.1 | Costs |
| 6.2 | Prioritising and commitment |
| 6.3 | Economic model |
| 6.4 | Economic thinking |

Table A3: Key dimensions, categories and higher order classifications.

| **Categorisation with key dimensions** | **Higher order classifications** |
|---|---|
| **National health policy:**<br>• The funding system<br>• Valuation system and financing<br>• Change the system of funding<br>• Policy central and local<br>• Cooperation reform<br>• Cooperation funding<br>• Cooperation reform (contracts).<br>• Privacy law | **Macro level** |
| **Regional and municipal policy and conditions:**<br>• Attitude to health service (holistic)<br>• Innovation and organization<br>• Municipal processes<br>• Prioritisation of non-statutory services<br>• Access to/continuity doctors<br>• Reorganisation | |

| | |
|---|---|
| • Unclear responsibilities<br>• Processes in hospital trusts | |
| **Inter-organisational implementation projects**<br>*Developing routines and procedures*<br>• Professional anchoring<br>• Agree on patient groups<br>• Technical limitations<br>• Missing routines<br>• Good routines<br>*Piloting and evaluation*<br>• Development of the service (equipment/referrals)<br>• Car and equipment<br>• Radiographers work environment<br>• Facilitation at the nursing home<br>• Importance of marketing<br>• Downtime<br>• Downtime-car and equipment<br>• Project-> operation<br>• Internal communication<br>• Information for next of kin<br>• Anchoring among employees<br>• Daily communication<br>• Documentation (research/evaluation)<br>• Regular follow-up and evaluation<br>*Collaborative culture*<br>• The dialog between the parties/ownership to the project.<br>• Project organisation<br>• Anchoring by means of cooperation<br>• Municipal management helps in the development of the service<br>• Collaborative culture<br>• Joint engagement<br>*Planning an efficient service*<br>• Adaption to local conditions<br>• Learn from past projects<br>• Positive experiences<br>• Electronic transmission of images and documents<br>• Profitability<br>• Large enough population basis<br>• Geographical area and efficiency<br>• Relieve the ambulance<br>• Response and report time<br>• Vulnerability and staffing<br>• Use<br>*Economical aspects*<br>• Anchorage in management<br>• Bureaucracy<br>• Contracts between the parties<br>• Project funding<br>• Financial security | **Meso level** |

| | |
|---|---|
| • Economic challenges<br>• Economic thinking hospitals/municipalities/communities.<br>• Silo thinking/holistic economic thinking<br>• Attitude to the funding<br>• Municipal costs<br>• Hospital costs<br>• Financial models<br>• Long-term commitment | |
| **Experienced outcome**<br>• Increased quality (patient, doctors and in general)<br>• Positive attitudes<br>• Advantage of the service<br>• Utility<br>• Negative experiences with radiology at the hospital.<br>• Human costs | **Micro level** |
| **Professional skills and personal characteristics**<br>• The initiator<br>• Leadership skills<br>• Promoters<br>• Motivation<br>• Radiographers attributes<br>• Patient centeredness<br>• Physicians role<br>• Radiographers role<br>• Reputation | |

# Attachments

REK
REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

| Region: | Saksbehandler: | Telefon: | Vår dato: | Vår referanse: |
|---|---|---|---|---|
| REK sør-øst | Gjøril Bergva | 22845529 | 12.02.2016 | 2015/2468 REK sør-øst D |
| | | | Deres dato: | Deres referanse: |
| | | | 08.12.2015 | |

Vår referanse må oppgis ved alle henvendelser

Elin Kjelle
Høgskolen i Buskerud og Vestfold

**2015/2468 Mobil røntgen for sykehjemspasienter: hindringer for opprettelse og drift, betydning for tilgang og kostnader**

**Forskningsansvarlig institusjon:** Høgskolen i Buskerud og Vestfold
**Prosjektleder:** Elin Kjelle

Vi viser til søknad om dispensasjon fra taushetsplikt i ovennevnte prosjekt. Søknaden ble behandlet av Regional komité for medisinsk og helsefaglig forskningsetikk (REK sør-øst D) i møtet 20.01.2016. Vurderingen er gjort med hjemmel i helsepersonelloven § 29 første ledd og forvaltningsloven § 13 d første ledd.

**Prosjektleders prosjektbeskrivelse**
*Helsetjenesteforskning: Forskningen skal gi oversikt over sykehjemspasienters bruk av røntgenundersøkelser og om mobil røntgen bidrar til bedre tilgang eller kvalitet på slike tjenester. Videre skal det beregnes kostnader mellom undersøkelser som gjennomføres på sykehjem sammenlignet med undersøkelse på sykehus. Forskningsspørsmål: Hvilke røntgenundersøkelser gjennomføres på sykehjemspasienter? Gir mobile røntgen en økning i antallet røntgenundersøkelser som gjennomføres på sykehjemspasienter? Er mobil røntgen kostnadseffektiv i hele sør-øst Norge? Det vil benyttes et kvantitative forskningsdesign med statistisk analyse av bruksfrekvens ved ulike sykehus/sykehjem. Det vil bli benyttet kost-effektanalyse med modellering for å beregne og sammenlikne kostnader mellom de to ulike undersøkelsesstedene som er tilgjengelig.*

**Vurdering**
Formålet med prosjektet er å gi en oversikt over sykehjemspasienters bruk av røntgenundersøkelser og om mobil røntgen bidrar til bedre tilgang eller kvalitet på slike tjenester. Det skal i tillegg beregnes kostnader mellom undersøkelser som gjennomføres på sykehjem sammenliknet med undersøkelse på sykehus.

Komiteen finner at prosjektet faller utenfor REKs mandat etter helseforskningsloven. Verken formålet med prosjektet eller det man reelt sett kan oppnå med prosjektet vil fremskaffe ny kunnskap om helse eller sykdom som sådan. Komiteen anser prosjektet som helsetjenesteforskning. Siden samtykke ikke skal innhentes er prosjektet avhengig av dispensasjon fra taushetsplikt.

REK er gitt myndighet til å kunne gi dispensasjon fra taushetsplikten for tilgang til taushetsbelagte helseopplysninger fra helsepersonell eller helsetjenesten for annen forskning, jf. helsepersonelloven § 29 første ledd og forvaltningsloven § 13 d første ledd. Komiteen er av den oppfatning at de samme vurderinger skal gjøres her, som ved vurdering av fritak av lovpålagt taushetsplikt etter helseforskningsloven §§ 15, 28 og 35. Relevante skjønnsmomenter i vurderinger foretatt etter helseforskningslovens bestemmelser er anvendt i komiteens vurdering av denne saken.

Det skal innhentes opplysninger fra røntgenjournal (RIS) fra 12 ulike sykehus i Norge. Opplysninger som skal hentes ut er: type røntgenundersøkelse, navn på henvisende sykehjem, undersøkelsessted i sykehjem eller på sykehus/legevakt. Det skal innhentes data fra om lag 10.000 pasientundersøkelser for perioden 1.1.2015-1.1.2016. Søker oppgir at opplysningene vil være indirekte identifiserbare.

Etter komiteens syn er data det bes om relevante for prosjektet. Komiteen finner at vilkårene for å innvilge dispensasjon fra taushetsplikten er oppfylt. Dette innebærer at opplysninger kan utleveres og sammenstilles som beskrevet i søknaden uten hinder av taushetsplikt.

Komiteen gjør oppmerksom på at REKs myndighet er begrenset til å vurdere om vilkårene for å gi dispensasjon fra taushetsplikt er oppfylt. Søker må ta kontakt med personvernombudet som gir behandlingsgrunnlag/konsesjon for opplysninger som inngår i forskningsprosjekter.

**Vedtak**
Prosjektet faller utenfor helseforskningslovens virkeområde, jf. § 2 og § 4 bokstav a).

Med hjemmel i Forskrift av 2.7.2009 nr. 989, Delegering av myndighet til den regionale komiteen for medisinsk og helsefaglig forskningsetikk etter helsepersonelloven § 29 første ledd og forvaltningsloven § 13d første ledd, har komiteen besluttet å gi fritak fra lovpålagt taushetsplikt.

Dispensasjonen fra taushetsplikt innebærer at opplysninger kan innhentes som beskrevet i søknaden uten hinder av taushetsplikt.

Følgende vilkår ligger til grunn for dispensasjonen:
• at prosjektet gjennomføres i samsvar med søknad og forskningsprotokoll
• det forutsettes at de nødvendige godkjenninger foreligger fra personvernombud eller Datatilsynet
• at eventuelle rapporter eller publikasjoner gis i en slik form at enkeltpersoner ikke kan gjenkjennes
• at personidentifiserbare opplysninger slettes, eller anonymiseres straks det ikke lenger er behov for dem og senest ved prosjektets avslutning.

Dispensasjonen fra taushetsplikt gjelder til 01.01.2020.

Klageadgang
REKs vedtak kan påklages, jf. forvaltningslovens § 28 flg. Klagen sendes til REK sør-øst D. Klagefristen er tre uker fra du mottar dette brevet. Dersom vedtaket opprettholdes av REK sør-øst D, sendes klagen videre til Den nasjonale forskningsetiske komité for medisin og helsefag for endelig vurdering.

Vi ber om at alle henvendelser sendes inn på korrekt skjema via vår saksportal: http://helseforskning.etikkom.no. Dersom det ikke finnes passende skjema kan henvendelsen rettes på e-post til: post@helseforskning.etikkom.no.

Vennligst oppgi vårt referansenummer i korrespondansen.

Med vennlig hilsen

Finn Wisløff
Professor em. dr. med.
Leder

Gjøril Bergva
Rådgiver

**Kopi til:** Høgskolen i Buskerud og Vestfold ved øverste administrative ledelse: postmottak@hbv.no

**Norsk samfunnsvitenskapelig datatjeneste AS**
NORWEGIAN SOCIAL SCIENCE DATA SERVICES

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Elin Kjelle
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p.b 235
3603 KONGSBERG

| Vår dato: 15.02.2016 | Vår ref: 45571 / 3 / MHM | Deres dato: | Deres ref: |
|---|---|---|---|

TILBAKEMELDING PÅ MELDING OM BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 09.11.2015. Meldingen gjelder prosjektet:

| | |
|---|---|
| *45571* | *Mobile x-ray services for nursing home residents: barriers and facilitators for implementation and sustanability, impact on access to services, and cost-effectiveness* |
| *Behandlingsansvarlig* | *Høgskolen i Buskerud og Vestfold, ved institusjonens øverste leder* |
| *Daglig ansvarlig* | *Elin Kjelle* |

Personvernombudet har vurdert prosjektet, og finner at behandlingen av personopplysninger vil være regulert av § 7-27 i personopplysningsforskriften. Personvernombudet tilrår at prosjektet gjennomføres.

Personvernombudets tilråding forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, ombudets kommentarer samt personopplysningsloven og helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/meldeplikt/skjema.html. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://pvo.nsd.no/prosjekt.

Personvernombudet vil ved prosjektets avslutning, 01.01.2020, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Vigdis Namtvedt Kvalheim

Marianne Høgetveit Myhren

Kontaktperson: Marianne Høgetveit Myhren tlf: 55 58 25 29

*Dokumentet er elektronisk produsert og godkjent ved NSDs rutiner for elektronisk godkjenning.*

# Personvernombudet for forskning

## Prosjektvurdering - Kommentar

Prosjektnr: 45571

Det er oppgitt at prosjektet er en nasjonal samarbeidsstudie. Høgskolen i Buskerud og Vestfold er behandlingsansvarlig institusjon. Personvernombudet forutsetter at ansvaret for behandlingen av personopplysninger er avklart mellom institusjonene. Vi anbefaler at det inngås en avtale som omfatter ansvarsfordeling, ansvarsstruktur, hvem som initierer prosjektet, bruk av data og eventuelt eierskap.

Det er oppgitt at prosjektet er en del av av et doktorgradsarbeid der formålet er å gi en oversikt over sykehjemspasienters bruk av røntgenundersøkelser og om
mobil røntgen bidrar til bedre tilgang eller kvalitet på slike tjenester. Det skal i tillegg beregnes kostnader mellom undersøkelser som gjennomføres på sykehjem sammenliknet med undersøkelse på sykehus.

REK har vurdert at prosjektet faller utenfor helseforskningslovens virkeområde, og har gitt dispensasjon fra taushetsplikten til uthenting av data (REK 2015/2468).

Data skal hentes fra sykehusenes Røntgen informasjonssystem (RIS) . Det skal innhentes opplysninger fra 12 ulike sykehus i Norge. Opplysninger som skal hentes ut er: type røntgenundersøkelse, navn på henvisende sykehjem, undersøkelsessted i sykehjem eller på sykehus/legevakt. Det skal innhentes data fra om lag 10.000 pasientundersøkelser for perioden 1.1.2015-1.1.2016.

Ifølge prosjektleder kan opplysningene være indirekte identifiserbare. Personvernombudet vurderer at opplysningene er relevante for formålet og at personvernulempen er liten forutsatt at ingen personopplysninger publiseres. Personvernombudet finner derfor at opplysningene kan behandles med hjemmel i personopplysningsloven § 8 d) og § 9 h) .

Som hovedregel skal utvalget informeres. Siden forsker ikke har tilgang til direkte personopplysninger eller kontaktinformasjon til utvalget, vurderer vi at det er uforholdsmessig vanskelig å informere og at forsker kan fritas fra sin informasjonsplikt med hjemmel i personopplysningsloven § 20 b).

Personvernombudet legger til grunn at forsker etterfølger Høgskolen i Buskerud og Vestfold sine interne rutiner for datasikkerhet.

Forventet prosjektslutt er 01.01.2020. Ifølge meldeskjema skal innsamlede opplysninger da anonymiseres. Anonymisering innebærer å bearbeide datamaterialet slik at ingen enkeltpersoner kan gjenkjennes. Det gjøres ved å:
- slette direkte personopplysninger (som navn/koblingsnøkkel)
- slette/omskrive indirekte personopplysninger (identifiserende sammenstilling av bakgrunnsopplysninger som f.eks. bosted/arbeidssted, alder og kjønn)

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Vår dato: 04.01.2016 Vår ref: 45739 / 3 / MHM Deres dato: Deres ref:

# TILBAKEMELDING PÅ MELDING OM BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 19.11.2015. All nødvendig informasjon om prosjektet forelå i sin helhet 30.12.2015. Meldingen gjelder prosjektet:

| | |
|---|---|
| *45739* | *Mobile x-ray services for nursing home residents: barriers and facilitators for implementation and sustainability, impact on access to services, and cost-effectiveness.* |
| *Behandlingsansvarlig* | *Høgskolen i Buskerud og Vestfold, ved institusjonens øverste leder* |
| *Daglig ansvarlig* | *Elin Kjelle* |

Personvernombudet har vurdert prosjektet og finner at behandlingen av personopplysninger er meldepliktig i henhold til personopplysningsloven § 31. Behandlingen tilfredsstiller kravene i personopplysningsloven.

Personvernombudets vurdering forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, ombudets kommentarer samt personopplysningsloven og helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/meldeplikt/skjema.html. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://pvo.nsd.no/prosjekt.

Personvernombudet vil ved prosjektets avslutning, 01.01.2020, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Katrine Utaaker Segadal

Marianne Høgetveit Myhren

Kontaktperson: Marianne Høgetveit Myhren tlf: 55 58 25 29

*Dokumentet er elektronisk produsert og godkjent ved NSDs rutiner for elektronisk godkjenning.*

# Personvernombudet for forskning

## Prosjektvurdering - Kommentar

Prosjektnr: 45739

Utvalget informeres skriftlig og muntlig om prosjektet og samtykker til deltakelse. Revidert informasjonsskriv mottatt 29.12.2015 er godt utformet, men det kan gjerne presiseres at prosjektslutt er 01.01.2020.

Det behandles enkelte opplysninger om tredjeperson. Det skal kun registreres opplysninger som er nødvendig for formålet med prosjektet. Opplysningene skal være av mindre omfang og ikke sensitive, og skal anonymiseres i publikasjon. Så fremt personvernulempen for tredjeperson reduseres på denne måten, kan prosjektleder unntas fra informasjonsplikten overfor tredjeperson, fordi det anses uforholdsmessig vanskelig å informere.

Personvernombudet legger til grunn at forsker etterfølger Høgskolen i Buskerud og Vestfold sine interne rutiner for datasikkerhet.

Forventet prosjektslutt er 01.01.2020. Ifølge prosjektmeldingen skal innsamlede opplysninger da anonymiseres. Anonymisering innebærer å bearbeide datamaterialet slik at ingen enkeltpersoner kan gjenkjennes. Det gjøres ved å:

- slette direkte personopplysninger (som navn/koblingsnøkkel)
- slette/omskrive indirekte personopplysninger (identifiserende sammenstilling av bakgrunnsopplysninger som f.eks. bosted/arbeidssted, alder og kjønn)
- slette digitale lyd-/bilde- og videoopptak

FORESPØRSEL OM DELTAKELSE I FORSKNINGSPROSJEKT

# MOBILE RØNTGENTJENESTER TIL SYKEHJEMSPASIENTER I NORGE

Ved Høgskolen i Sørøst-Norge gjør vi nå et forskningsprosjekt for å kartlegge røntgentilbudet til sykehjemspasienter i Norge. Vi vil kartlegge hva som hindrer og tilrettelegger for mobile røntgen tjenester i det norske helsevesenet, og ønsker dine innspill som leder og beslutningstager. Kartleggingen består av to deler en intervjudel og en del med spørreskjema.

## HVA INNEBÆRER DITT JA?

Vi ønsker et 45 minutters intervju med deg. Spørsmålene vil omhandle din erfaring med det å beslutte, innføre og drifte mobile røntgentjenester. Intervjuet vil bli tatt opp på lydbånd. I prosjektet vil vi i tillegg innhente informasjon om type organisasjon du arbeider. Resultatene av intervjuet skal benyttes i utviklingen av et spørreskjema som skal brukes i del to av kartleggingen.

## MULIGE FORDELER OG ULEMPER

Det er ingen ulemper eller risiko knyttet til deltagelse i forskningsprosjektet.

## FRIVILLIG DELTAKELSE OG MULIGHET FOR Å TREKKE SITT SAMTYKKE

Det er frivillig å delta i prosjektet. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på neste side. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke. Dersom du trekker deg fra prosjektet, kan du kreve å få slettet innsamlede opplysninger, med mindre opplysningene allerede er brukt i vitenskapelige publikasjoner.

Dersom du senere ønsker å trekke deg eller har spørsmål til prosjektet, kan du kontakte Elin Kjelle, tlf: 31009803, e-post: elin.kjelle@hbv.no

## HVA SKJER MED INFORMASJONEN OM DEG?

Informasjonen som registreres om deg skal kun brukes slik som beskrevet i hensikten med studien. Du har rett til innsyn i hvilke opplysninger som er registrert om deg og rett til å få korrigert eventuelle feil i de opplysningene som er registrert.

Alle opplysningene vil bli behandlet uten navn eller andre direkte gjenkjennende opplysninger.

Prosjektleder har ansvar for den daglige driften av forskningsprosjektet og at opplysninger om deg blir behandlet på en sikker måte. Informasjon om deg vil bli anonymisert eller slettet senest 01.01.2020.

## GODKJENNING

Prosjektet er godkjent av Norsk Samfunnsvitenskapelige Datatjeneste (NSD) (45739).

# SAMTYKKE TIL DELTAKELSE I PROSJEKTET

## JEG ER VILLIG TIL Å DELTA I PROSJEKTET

Sted og dato

Deltakers signatur

Deltakers navn med trykte bokstaver

Jeg bekrefter å ha gitt informasjon om prosjektet

Sted og dato

Signatur

Rolle i prosjektet

Doctoral dissertation no. 32
**2019**
—

**Mobile radiography services in nursing homes - utilisation, costs and organisation**

Dissertation for the degree of PhD

—

Elin Kjelle

—

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