Title: Cost-analysis of mobile radiography services for nursing home residents in Southeast Norway

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Abstract

i Rationale, aims and objective

Telemedicine applications such as mobile radiography services, provides a new way of organizing the healthcare services. When introducing telemedicine services, it is important to assess the economic outcome of the new service. With an aging population, the number of nursing home residents are expected to increase. In order to provide a safe and personalised care for nursing home residents to attend X-ray examinations, mobile radiography services have been implemented in several areas of Norway as well as in Sweden, Switzerland, Italy and Australia. Previous research have evaluated costs of X-ray examinations in urban areas of Norway and Sweden. Costs of treatment given after the X-ray examinations have not been evaluated. In addition, the costs of mobile radiography services in both urban and rural areas are unknown. The objective of this study was to analyse costs of X-ray examination and treatment of nursing home residents when comparing hospital-based imaging with a combination of hospital-based imaging and a mobile radiography service in Southeast Norway.

ii Methods

A decision model was constructed using the software TreeAge Pro, based on current knowledge of mobile - and hospital-based radiography imaging in Southeast Norway. The model include two alternatives; mobile radiography service in combination with hospital-based imaging, compared to hospital–based imaging alone. Treatment needed based on the examination result could be given either in the nursing home or at the hospital, depending on the residents condition. Transition 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 analysis was applied.

iii Results

The analysis showed a mean cost of € 2 790 per resident for hospital-based service alone. For mobile and hospital-based service combined, the mean cost was € 1 946 per resident, including examinations and the immediate treatment given. This difference in costs was significant (p <0.001). The cost reduction are mainly due to less hospitalizations and a reduction of ambulance transfer.

iv Conclusion

Mobile radiography service in nursing homes provide a safe, high quality healthcare service. The result of this study showed a 30% cost-reduction by implementing mobile radiography service.

1 Introduction

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

According to statistics from the hospital trusts (E. Kjelle et al., unpubl. study), 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 hospital. Examination in a hospital gives easy access to other specialist treatments and diagnostic tests [7]. However, for these fragile residents and especially those living with dementia, new surroundings such as the imaging department may lead to anxiety, delirium and injuries [6,8,9]. In addition, inpatient treatment at hospital are more costly than treatment in a nursing home [10]. The alternative would be a mobile radiography service, were a radiographer perform the X-ray examination in the residents' room at the nursing home [9,11-13], (with adequate quality image) [9,11,14]. Thus, allowing 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 developing delirium [15]. The imaging department at the hospital takes the investment costs of a mobile radiography service (a vehicle, X-ray equipment and operation costs). The gains due to less transportation and hospitalization is in the favor of other departments or institutions [15-18].

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 [19-21]. Previous research has established that a mobile radiography service reduce the cost per examination in urban areas [19-21], 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 have not been taken into account [19-21].

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

2 Methods and materials

Institutional setting of 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 are 82.3 years. In Southeast Norway, 21 393 persons resided in Nursing Homes in 2016. The region contains both densely and sparsely populated areas.

Mobile radiography services was implemented in 5 out of 8 public hospital trusts in Southeast Norway (Oslo university hospital, Akershus university hospital, Vestre viken hospital trust, Vestfold hospital trust and Østfold hospital trust) in the period of 2004-2013. The remaining hospitals in the region have hospital-based imaging only [15]. The mobile radiography services covers 33 out of 75 municipalities in the region. More details on the demographics of the region are presented in Table 1.

Please insert Table 1 here

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)* including two alternatives of service organization.

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

The alternatives in the model are presented in Fig. 1. Due to the fact that mobile radiography services run daytime on weekdays only, nursing homes residents may need a hospital X-ray examination outside this timeframe [12,13], e.g. falls in the weekend or an acute situation at night that indicate an X-ray examination. In areas with only hospital-based imaging, 10-20% 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 [12,13,22]. These residents were

assumed to be treated in the nursing home based on clinical diagnosis alone [12,13,22]. If treatment was needed after the X-ray examination, treatment could be given in a nursing home or at hospital either as outpatient or inpatient treatment [11-13,22].

Please insert Figure 1 here

Transition probabilities in the decision model

Probabilities on whether residents were examined in 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 indicated that 76% of the nursing home residents who were X-ray examined needed treatment as a result of the findings in the image [12,13]. 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, [11-13]. 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, of these 23% were admitted [12,13,22]. The transition probabilities are presented in Table 2, all probabilities are entered as beta distributions where appropriate.

Please insert Table 2 here

Costs used in the decision model

All residents in nursing homes need to be examined by a physician for referral, and the regulated physician visit fee was used [23]. According to Hektoen [10], this fee should be doubled in order to account for operating costs. For an X-ray examination in hospital, salary for radiographer, capital costs of equipment and facilities, and operating costs are included for chest, hip and pelvic examinations (Cost per patient at Oslo University hospital, Unpubl.). In the case of an X-ray examination in a nursing home the labour of a radiographer, transportation, capital costs of equipment and vehicle, and overhead costs are included for all types of general X-ray examinations

[24]. According to earlier research, 50-88% of nursing home residents use ambulance to transfer to hospital [12,13,22,25]. Thus, 70% of the residents were assumed to need ambulance transfer And the rest of the residents are assumed to use a taxi. Costs of taxi transfer were calculated as average km travelled times cost per km with a start fee. Based on data from the eight hospital trusts in southeast Norway, on the average travel distance was 27.08 km between nursing homes and hospitals. According to Lærum et al. [22] 75% of residents were in need of nursing home personnel to accompanying them to the hospital. Thus, 25% of residents are assumed to be accompanied by an adult family member, spending one workday accompanying the resident [11,22].

Treatment of hip fractures and pneumonia are used for valuing the cost of inpatient hospital treatment through the Norwegian DRG codes [26]. These are assumed to be the most common treatments related to hospitalization after an X-ray examination of nursing home residents [4,6]. Cost of outpatient treatment was calculated from the Norwegian DRG for outpatient treatment of pneumonia infections and minor fractures [26]. Moderate and mild pneumonia and several other minor conditions could be treated at a nursing home [4,6]. For valuing nursing home treatment, an average of 7 days of treatment and care with a multi-disciplinary team were assumed [10]. Costs of services that would remain the same regardless of where the examination took place were omitted (e.g. reporting costs and administrative handling of referrals). Costs are presented in Table 3, costs are entered as gamma distributions in the model where appropriate.

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

Please insert Table 3 here

Statistical analysis

With TreeAge, in order to evaluate the impact of parameter uncertainty, probabilistic sensitivity analysis (PSA) was used [27]. SPSS (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.) was used for descriptive statistics and paired-samples t-test.

3 Results

The calculated costs per examined and treated resident with hospital-based imaging was on average € 2 790. The average costs per resident with the combination of mobile- and hospital-based service was € 1 946 (table 4). This constitutes a 30% cost reduction per resident. Considering there were at least 7 375 X-ray examinations for nursing home residents in Southeast Norway in 2015, this would amount to a cost reduction of just above € 6 224 000.

Please insert Table 4 here

The illustration of the Monte Carlo probability distribution of cost difference of the compared alternatives are shown in Fig 2. The alternative with a combined service gave a cost reduction in all 1 000 runs compared to hospital-based imaging alone. The cost reduction would most likely be €560-€1 080. A paired-samples t-test was used to evaluate the difference in cost between the two alternatives further. The cost reduction in the combined alternative was significant, mean cost reduction of € 844 with a 95% Confidence Interval ranging from € 837 - € 851 (SD=112.4), p <0.001 (two tailed).

Please insert Figure 2 here

4 Discussion

This cost analysis presents a cost comparison of two alternative organizations of radiography services. Hospital-based imaging compared with hospital-based and mobile radiography services combined. The analysis demonstrated that the combined mobile and hospital-based X-ray service provides a 30% cost reduction compared with hospital-based imaging only. In addition, there is a possibility for even higher cost reduction if the radiographer examines more than one patient at each

nursing home visit. Randers [21] calculated 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.

Quality of treatment and care

The effects of mobile radiography services have not been evaluated in this study. However earlier research have shown mobile radiography services to facilitate high quality treatment and care [15]. According to Ranhoff and Linnsund [5] nursing home residents would in most cases be better of treated in the nursing home. Providing adequate treatment and in the nursing homes would in many cases be easier when diagnosis is supported by imaging [18,22]. Mobile radiography services would thus facilitate better treatment and care for residents unable to travel and may increase quality of life for residents who no longer need to travel back and forth for the X-ray examination alone [5,11,13,22].

Transfer and hospitalization

The cost reduction was mainly due to reduction in transportation and the number of hospitalizations. A transfer by ambulance is costly (compared to transfer the X-ray equipment) both economically and considering the residents condition health [19,21]. Previous research have calculated costs with mobile radiography services in relative highly populated areas in Norway and Sweden, with a mean travel distance of 10-20 km [19-21]. This cost analysis included both highly and sparsely populated areas with a mean travel distance of 27 km. In areas were 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 [20]. However, the cost reduction per examination and treatment would be high (because of transfer costs increasing in addition to the increase in) due to transportation costs including accompanying staff or family members [20,21]. Further, the strain on the residents may increase with time away from the nursing home [22]. Due to long travel distance to hospitals in rural areas, the transfer could cause residents to not be examined or that the transfer in itself would

cause hospitalization [6,8,9,22]. 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 [5,13,15].

Silos in healthcare

In Norway, the responsibility for healthcare services are divided between municipalities (primary healthcare – e.g. nursing homes) and regional health authorities (specialist healthcare– e.g. hospitals) [16]. The different departments in each hospital or municipalities are responsible for their own budget [16]. This may lead to a silo effect within the healthcare services. Setting up a mobile radiography service, the investment costs are large for the imaging department. The change in service delivery leads to a cost-reduction in other hospital departments and the municipalities, due to reduction in transfer and hospitalization [15-18]. Thus, the imaging department would not benefit from their investment. Such division may obstruct the introduction of a mobile radiography service [18].

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 alternatives. Especially the assumptions on costs of treatment and ambulance transportation do have a high influence on the result. Notwithstanding it limitations, this study provides evidence that mobile radiography reduce healthcare costs in southeast Norway based on the best data available at the time.

Implications for practice and further research

Telemedicine applications such as mobile radiography services, provides a new way of organizing healthcare services. When introducing telemedicine services, it is important to assess the economic outcome of the new service [28]. This could contribute to a wider use of mobile radiography services as it serves to provide knowledge needed for managers in healthcare to make decisions on

implementation of change in healthcare organizations. Further research is needed on the effects of this service in order to be able to perform cost-effectiveness analysis. Further, other imaging modalities, such as Computed Tomography or Ultrasound could be mobilised in a similar manner. The benefits for the residents on staying in their familiar environment may be similar. Thus, cost- or cost-effectiveness analysis of mobilising these modalities would be interesting in order facilitate better resource allocation in healthcare in the future.

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

5 Acknowledgements

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7 Figure legends

Figure 1: An illustration of the developed decision model, with the alternatives for examination and treatment.

Figure 2: Monte Carlo Probability distribution.

8 Tables

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)†	Population density (per km^2)*	Nursing home beds (n)*	Municipalities included/ total number of municipalities (n)	Population density in included area (per km^2)
Oslo university hospital	6	1564	4444	1/1	1564
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	-

†Data from hospitals, *Numbers from Statistics Norway

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	[12,13]
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	[11,13]
Inpatient treatment	0.075 (0.003)	0.0749-0.0752	[12,13]
With hospital-based imaging only			
To be examined	0.835 (0.02)	0.834-0.836	[12,13]
Treatment after hospital X-ray			
Treatment in nursing home	0.68		[12]
Inpatient treatment	0.23 (0.05)	0.23-0.236	[12,13,22]

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	References
Medical examination in nursing home	66		[10,23]
Ambulance one way	650		[24]
Taxi one way†	88.5 (8.8)	88-89.1	[13,29]
Accompanying personnel – 1 day	242 (2.4)	242-242.3	[10]
Accompanying family member - 1 day	215		[30]
X-ray examination in nursing home	144		[24]
X-ray examination in hospital	100 (11)	99.7-101	*
Inpatient treatment	6 753 (1540)	6 649-6 857	[26]
Outpatient treatment	192 (22)	191-194	[26]
7 days of treatment in nursing home	2 219 (104)	2 212-2 225	[10]

† Average 3 €/km charge. Mean start fare of € 5 [31].
*Cost per patient (CPP) at Oslo University hospital Unpubl.

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

Alternatives	**Mean € (SD)**	**95% CI**
With mobile radiography service	1 946 (139)	1 937-1 954
Without mobile radiography service	2 790 (138)	2 782-2 799