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Omitting Routine Chest Radiographs in Intensive Care Units



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The Economic Impact

We studied the economic impact of omitting routine chest radiographs (CXR) in a university ICU. Additionally, we performed a prospective observational micro-costing exercise to identify the current costs of radiodiagnostic pathways, and compared the CXR cost calculation between a university hospital and a regional hospital ICU.

Anteroposterior chest radiographs (CXRs) are often obtained daily from patients in intensive care units (ICUs) in addition to a physical examination (Godoy et al. 2012; Trotman-Dickenson 2003). The detection of complications associated with indwelling devices as well as the timely recognition of cardiopulmonary afflictions can lead to earlier treatment of clinically unsuspected problems. Therefore various guidelines recommend routine CXRs, especially in patients receiving mechanical ventilation or suffering from acute cardiopulmonary disorders (Amorosa 2008). In contrast, a more restrictive approach limits CXRs to specific clinical indications like placement of indwelling devices or a change in the patient's respiratory status (Clec'h et al. 2008; Graat et al. 2006; Graat et al. 2007; Hejblum et al. 2009; Hendrikse et al. 2007; Krivopal et al. 2003; Silverstein et al. 1993). Those studies have questioned the medical benefit of routine CXR in ICU patients. Furthermore, restrictions in performing CXRs in ICUs may help to decrease healthcare costs, reduce radiation exposure, and avoid unnecessary treatment of minor or false positive findings (Brainsky et al. 1997; Fong et al. 1995; Hendrikse et al. 2007; Krivopal et al. 2003; Leppek et al. 1998; Price et al. 1999). Also the positioning of critically ill patients can lead to adverse events like malpositioning of devices, which also can be minimised by the strict limitation of radiographs to particular clinical indications (Boulain 1998).

Economic and clinical costs associated with routine CXRs have to be taken into account. In general, avoidable costs should be minimised, without limiting diagnostic quality, to ensure an optimal distribution of financial resources. Hence the omission of routine CXRs in ICUs can lead to substantial cost savings without degrading the quality of medical care (Price et al. 1999). The aim of this study was to analyse the real costs of radiodiagnostic pathways in ICUs and investigate the potential cost savings due to the elimination of routine CXRs and the restriction of radiographs to specific clinical indications.

Materials and Methods Study Design

The study was planned in three parts. First we performed a prospective observational microcosting exercise for one week in five ICUs at the university hospital of Vienna, Austria, to analyse the current costs of radiodiagnostic pathways. During this period daily routine CXRs were obtained from every patient admitted. The requirements of personnel and consumable materials to obtain radiographs were assessed and compared with the corresponding cost accounting. Through pathway construction each process of radiodiagnostic examination (RDE) was individually analysed in order to charge overall costs by activity-based costing. Secondly, the application and costing of CXRs in the university hospital and a regional hospital (Landeskrankenhaus Amstetten, Lower Austria, Austria) were compared to reveal differences in CXR cost accounting and application management. Thirdly, we analysed cost savings due to elimination of daily CXRs in a university ICU, including data on all admitted patients, six months before and six months after routine CXRs were eliminated. All costs are given in Euros.

Study Locations

The micro-costing study was conducted in five ICUs of the university hospital of Vienna, Austria. Each ICU is an 8-bed closed-format department (4 sickrooms each) in which medical and surgical patients (including cardiothoracic surgery and neurosurgery patients) are under the direct care of the ICU team. During daytime the patients of one ICU are under the observation of up to two ICU physicians and residents. At night or at the weekend the on-call ICU team comprises one ICU physician and one resident.

In Amstetten hospital the ICU is an 8-bed closed-format department with medical and surgical patients. Cardiothoracic surgery and neurosurgery are not performed in this hospital. The ICU team comprises one physician and one resident during the day and one physician during the night or at the weekend.

Micro-costing

To estimate the costs of RDEs in university ICUs each process was individually analysed by activity-based costing. The personnel requirement as well as the consumable material was reported via questionnaires, which were completed for every obtained CXR by the staff involved. This observational phase was conducted over one week in five ICUs at the university hospital of Vienna, Austria. At that time daily routine CXRs were standard procedure and the data were collected for every patient receiving a CXR within the study week, including repeated radiographs for the same patient. The questionnaires comprised the number and the qualifications of all involved employees as well as the consumable material used and the time needed to obtain the individual CXRs (including the time needed to cart the mobile x-ray apparatus from the base to the first ICU, from one unit to another and between sickrooms). The patients' diagnosis and treatment, including respiratory status and extracorporeal circuits, were documented separately. Patients suffering from infectious diseases were described in particular, due to the increased effort to obtain the CXR. Further, the time needed to examine every individual radiograph, including the diagnosis and discussion with the ICU physician, was documented by the radiologist on duty. The data retrieved was compared with the correspondent in-house cost accounting.

Before-After Study

Between January and June 2010 the number of CXRs was retrospectively assessed for all patients in one university ICU as well as in the ICU in the tertiary hospital of Amstetten. The number of treated patients, their length of stay and intensive scores were collected and compared between locations. At that time daily CXRs were standard procedure in the university ICU, and for ventilated patients only in Amstetten.

In the second half-year period, CXRs in the university ICU were limited to specific indications, e.g. the insertion of indwelling devices, an increase in oxygen requirement, or in pulmonary secretion. CXRs at admission were conducted only if in the shortterm no previous radiograph was available or after insertion of central venous lines. Daily CXRs were performed in accordance with the guidelines of the Royal College of Radiologists (2003). For this period the number of CXRs and the patients' data were also collected as for the first half-year 2010. Furthermore, the number of computed tomography (CT) scans on demand was assessed separately for the two periods in order to assess a potential change in the usage of other imaging techniques.

Statistical Analysis

Demographic data were extracted from the ICU databases. Data are expressed as mean and standard deviation unless otherwise stated. Statistical analysis was performed with GraphPad Prism Version 5.01 (GraphPad Software, Inc. San Diego, CA, USA). Demographic data of patients admitted to Amstetten or to the university ICU in the second half-year 2010 were statistically compared to patients admitted to the university ICU in the first half-year 2010. The numbers of patients in the patients' subgroups, the numbers of survivors, and the number of males/females were compared with X2 analysis, with $p < 0.05$ considered significant. The patients' age and SAPSII score as well as their length of ICU stay were analysed with the two-tailed Mann-Whitney U test, with $p < 0.05$ considered significant.

Results Micro-Costing

During the study period the time to obtain a CXR was measured for 46 patients, and the examination time was documented for 41 patients by the radiologist on duty. 19 patients were mechanically ventilated via tube and five patients were infected with a multiresistant pathogen. Every CXR was obtained by a technician. If the patient was mechanically ventilated additional help from the nursing staff present were necessary. The

examination and discussion was conducted by a resident of radiology and a resident of intensive care medicine. However, the official in-house cost accounting considered a technician to obtain the CXR as well as an assistant, whose help was essentially not required. On the contrary, the intervention of the nursing staff was not accounted for. The official cost accounting included one medical doctor to examine the CXR, without appraisal of his/her qualifications.

The account of time taken shows that all radiodiagnostic measures within one university ICU lasted 24 minutes and the examination for all patients within one university ICU 13 minutes.

The finance department computed the following working time for one CXR: 25 minutes for a technician, 5 minutes for a medical doctor and 10 minutes for an assistant, whose help was essentially not required.

The consumable material to obtain CXRs from non-infectious patients comprised disinfection material, disposable gloves and aprons. For patients suffering from multiresistant pathogens surgical masks, surgical caps, surgical coats, and wrapping for the x-ray film cartridge were additionally needed. The official cost accounting deemed an x-ray film per CXR - although the CXRs were already saved digitally at that time – but no further consumable material necessary.

University Hospital Versus Regional Hospital

Within the same time period 78 patients were admitted to the regional ICU versus 248 patients in the university ICU. The patients were comparable in age, sex, and severity of disease, but differed in length of stay and mortality (see Table 1).

	Regional hospital	University hospital	
	first half-year	first half-year	second half-year
No. of patients	80	248	258
No. of patients per bed	10	31	32
Age (years, mean, SD)	63 (19)	60 (16)	57 (18)
Gender male (n, %)	49 (61%)	146 (59%)	168 (6 %)
Length of stay/ patient in ICU (days, SD)	12.7 (14) **	5.8 (6)	5.6 (9)
SAPS II score (mean, SD)	31 (13.2)	32.9 (13.6)	32.2 (15.1)
Non-survivor (n, %)	25 (20%)**	17 (7%)	25 (1%)
No. of CXRs	751	1254	828
CXRs per patient	9.4	5.1	3.2
CXRs per patient per day	0.7	1.1	0.6
Estimated costs per CXR (Euro)	23.36	54.30	54.30
Costs for CXRs/ patient (Euro)	218.7	274.6	174.3
Costs for CXRs/ patient/day (Euro)	19.2	57.2	34.2
No. of CT		145	97

Patient subgroups			
Medical (n)	30*	50	56
Cardiovascular surgery (n)	2	21	22
Neurosurgery (n)		11	6
Thoracic surgery (n)		12	11
Transplantation (n)		11	9
Trauma (n)	28**	23	20
Gastrointestinal surgery (n)	20*	32	46
Other (n)		49	60
Unknown (n)		39	28

Table 1. Demographic Data

Asterisks depict the significance compared to data of the university hospital in the first half-year (* $p < 0.01$; ** $p < 0.001$). The patients did not differ significantly in age, sex or sAPsii score between all compared groups. The patients admitted in the first and the second half-year 2010 to the university ICU did not differ between the patients' subgroups or mortality.

sAPs ii, simplified Acute Physiology score; CXR, Anteroposterior chest radiographs.

Amstetten charged 23.36 Euro per CXR consisting of 10 minutes working time for two technicians, consumable material, initial costs as well as costs of upkeep, administration, and electricity. The medical examination was not accounted. In the university hospital, the finance department estimated a charge of 54.30 Euro per CXR, which included the medical examination.

Additional costs, such as depreciation of capital goods like the radiologic scanner, the printer or the x-ray viewing screen, were not specified in both hospitals. Unlike the university hospital, the finance department in Amstetten differed between CXRs obtained from ICU patients or out-patients. Daily costs for CXRs per patients accounted for 19.2 Euro in the regional hospital in contrast to 57.2 Euro in the university hospital. Charges for one patient amounted to a total of about 200 Euro in Amstetten versus 270 Euro in Vienna.

Before-after Study

In the first half-year 2010 (1 January-30 June) 1254 CXRs were obtained from 248 patients in the university ICU (see Table 1). In the second half-year (1 July-31 December) daily routine CXRs were abandoned and radiographs were limited to specific indications. During this period 828 CXRs were obtained from 258 patients, a reduction of 34%. From January till June 5.1 CXRs per patients were performed, versus 3.2 from July till December. Apparently the reduction of radiographs had no effect on the patients' mortality or length of ICU stay (see Table 1). Since real costs could not be determined by our study the charges set by the finance department were used for cost saving calculation. As 54.30 Euro were estimated per CXR by the finance department, the decreased usage of radiographs led to a calculated cost reduction of about 23,000 Euro. The daily costs for radiographs per patients per day dropped from 57 Euro to 34 Euro. Total cost savings amounted to about 100 Euro per patient (see Table 1). Interestingly, the number of demanded CT interventions also decreased from 145 in the first half-year to 97 in the second half-year, leading to a calculated cost reduction of about 13,500 Euro, as 280.11 Euro were charged per CT examination by the finance department.

Discussion

CXRs are frequently obtained daily to early detect cardiopulmonary complications in patients admitted to ICUs. In contrast, recent publications question the diagnostic and clinical value of routine RDEs (Clec'h et al. 2008; Graat et al. 2006; Graat et al. 2007; Hendrikse et al. 2007; Kappert et al. 2008; Price et al. 1999). Those studies demonstrated that daily CXRs rarely reveal clinically relevant abnormalities. Furthermore, the omission of routine CXRs had no effect on the patients' outcome or readmission rate, but led to cost savings and economic benefits. Clec'h et al. were even able to demonstrate that the restrictive usage of CXRs was associated with better diagnostic and therapeutic efficacy than daily routine use (Clec'h et al. 2008). Based on those findings we analysed the financial impact of omission of routine CXRs in a university ICU. Further, we investigated each process of RDEs via pathway construction and compared the cost calculation with real time and effort

measured.

In most European countries healthcare costs are usually not borne by the individual patient but by health insurance. As a consequence, economic pressure to change routine examinations is barely present as long as the patients' security is assured. Due to daily changes in medical personnel, routine CXRs have been standard procedure in our department in order to compensate for potential deficits in medical handover. Because of emerging economic pressure, traditional procedures like routine RDEs have been increasingly questioned, leading to the omission of daily CXRs in our ICU. As a result, the limitation of RDEs to defined clinical indications caused a reduction of radiographs of 34% within six months. Thereby the analysed before and after patient cohorts were comparable, with no statistical significance in age, sex or severity of illness. In accordance with the literature we also could not observe any differences in mortality or in length of ICU stay attributed to the omission of daily CXRs. Since daily radiodiagnostic controls were not available any more, the number of ordered CT interventions might subsequently have been increased in order to overcome this limitation. Interestingly the number of CT examinations even decreased, which is in accordance with the study of Kroner et al., who showed that limitation of daily radiographs had no impact on number or implication of CT and ultrasound examinations (Kroner et al. 2008).

The omission of daily routine CXRs in the university hospital led to calculated cost savings of about 23,000 Euro within six months for one 8-bed ICU. Daily CXR charges per patients were reduced by half, resulting in an overall cost saving of about 100 Euro per patient. This is in accordance with Price et al., who also demonstrated the financial impact of an evaluation and subsequent change in CXR ordering practice in a paediatric ICU, leading to fewer radiographs per patients and consequently to cost reduction (Price et al. 1999). The reduced demand of CT examinations in our ICU resulted in cost savings of about 13,500 Euro for a time period of six months.

Our analyses of RDEs by activity-based costing via pathway construction revealed a mismatch between accounted and real costs. We demonstrated that RDEs in ICUs are less time-consuming than expected, even when the patients were mechanically ventilated or infectious. Working time, the most important cost item, was overestimated in the official cost calculation by about 90%. This difference in charged and real working time might derive from preset values, which have been used for cost calculations. Although radiographs were saved digitally at time of investigation, the cost accounting still calculated CXR costs based on x-ray films but no consumable material, energy costs or additional charges. Thus, accounting costs do not correlate with real effort, but unfortunately we were not able to ascertain real costs within this study. In the regional hospital CXR cost calculation differed from the university hospital. Cost accounting in the regional hospital was more accurate and even differentiated between patients admitted to ICUs and outpatients. In contrast, medical appraisal of findings was not considered in CXR cost calculation. In the regional as well as in the university hospital charges for capital goods such as the radiologic scanner, the printer and x-ray viewing screens were not accounted for in CXR cost calculation and might therefore have been included elsewhere.

In the regional hospital, daily CXRs were standard procedure for ventilated patients only, whereas for other patients RDEs were restricted to clinical indications. The patient population was comparable in age, sex, and severity of disease, but differed in patient subgroups and consequently in length of ICU-stay and the patients' mortality. Due to their longer hospitalisation, patients in the regional hospital received more CXRs.

Conclusion

Our study demonstrates the substantial impact that changes in routine tests and clinical management may have on economic costs. Therefore routine procedures should be regularly questioned on their contribution to diagnosis, economic aspects and the patients' benefit to enable an optimal distribution of resources. Moreover, cost calculations should be regularly adapted to reflect the real use of resources.

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