OPTIMIZATION OF CHEST RADIOGRAPHY PRACTICE FOR CRITICALLY ILL PATIENTS

Martijn Tolsma

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Verslag X-Thorax.
De medische gegevens en vraagstelling vermelden het woord ‘controle’
zonder dat daarbij vermeld wordt wat ik moet controleren.
Aan hart en longen zie ik geen afwijkingen.

G.P.J. Geenen, radioloog

Man, in this life, you gotta do what you want.
You gotta let your mind and flow, flow free.

Jimi Hendrix

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Chapter 1

General introduction and aims of the thesis

M. Tolsma
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GENERAL INTRODUCTION

The chest radiograph (CXR) has firm roots in the intensive care unit (ICU) and is frequently performed routinely (daily, at ICU admission, after surgery and following other certain procedures) or in a more 'on-demand' manner for certain clinical circumstances like respiratory and circulatory problems. The evidence on an appropriate CXR practice for ICU departments has been conflicting during the last decades, ranging from observational studies in the early 80s of the last century to randomized trials, meta-analysis and review articles in the 21th century.

The first observational studies still recommended performing CXR for ICU patients on a routine basis because of the high efficacy due to the high incidence of new findings [1-4], and this has been a common practice around the world for decades. In addition to the number of findings, others stated that physical examination is not a valid alternative for performing CXRs in certain clinical conditions [5-6]. Later, larger observational studies reported a low efficacy of routine CXRs in a general ICU population or for mechanically ventilated patients only, and these investigators started to debate the practice of routine CXRs [7-12]. Studies on the value of routine CXRs at ICU admission or after procedures, like central venous catheterization, endotracheal intubation or chest tube placement or removal, also reported a low efficacy [13-21].

In the current century, multiple investigators compared a routine CXR strategy to an on-demand only CXR strategy and found no difference in important outcome measures like mortality, duration of mechanical ventilation, ICU length of stay, hospital length of stay, number of ICU readmissions and the number of requested alternative imaging studies as ultrasound or computed tomography [22-28]. Now the evidence suggested that a more restrictive CXR strategy should be safe and that this approach could have additional advantages such as a reduction in false positive CXR results, costs, personnel workload and irradiation to the patients.

Meanwhile, however, a 2006 survey on Dutch intensivists revealed that an important number of ICUs still practiced a routine CXR strategy [29]. Intensivists still showed to assume a far higher value of these CXRs than the efficacies that were reported in the literature. A routine strategy was performed in nearly all centers for cardiothoracic surgery patients, which seem to be a specific patient group in this topic [29], despite the promising alternative of bedside ultrasound by ICU physicians [30-31]. Subsequently, a recent meta-analysis by Ganapathy and colleagues [26] stated that, in all routine versus on-demand studies, the confidence intervals and study populations were small, and missed findings and possible harm in a restrictive CXR strategy was not assessed enough.

Obviously, the discussion regarding the optimal CXR practice for critically ill patients is still ongoing nowadays. It seems hard to implicate the evidence into the clinical practice in this area. Most ICU departments seem to have no clear protocol regarding their CXR indications and often the least experienced doctors or the nursing staff may request these CXRs. Why do intensivists still assume a high value of routine CXRs despite the evidence? It should be considered that CXRs with this low diagnostic efficacy, thus even when there are no important findings, might have certain importance for patient management that is not studied before. This may hypothetically concern documentation of disease progress and response to therapy, but also workflow, efficiency and certain clinical decision-making [32].

AIMS OF THE THESIS

Since the discussion regarding the optimal CXR practice for ICU patients is still ongoing these days, despite the available evidence, we had different aims with our research towards this topic. In chapter 2 we present a renewed survey on Dutch intensivists and their current (2014) CXR practice. In chapter 3 we hypothesize on potential additional values of CXRs and CXRs with negative findings that are not studied before. In chapters 4, 5 and 6 we focus on the value of routine CXRs for the specific groups of conventional cardiothoracic surgery patients and minimally invasive cardiac surgery patients. We also present the results of a new, more restrictive, CXR approach for conventional postoperative cardiac surgery patients (chapter 5). Finally, in chapters 7 and 8 we attempted to study the relevance of routine CXRs with negative findings, and we investigated which CXR indications are important for intensivists regarding their clinical decision-making and patient logistics.

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Chapter 2

Significant changes in the practice of chest radiography in Dutch intensive care units: a web-based survey

M. Tolsma
T.A. Rijpstra
M.J. Schultz
P.G.H. Mulder
N.J.M. van der Meer

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ABSTRACT

Background. Intensive care unit (ICU) patients frequently undergo chest radiographs (CXRs). The diagnostic and therapeutic efficacy of routine CXRs are now known to be low, but the discussion regarding specific indications for CXRs in critically ill patients and the safety of abandoning routine CXRs is still ongoing. We performed a survey of Dutch intensivists on the current practice of chest radiography in their departments.

Methods. Web-based questionnaires, containing questions regarding ICU characteristics, ICU patients, daily CXR strategies, indications for routine CXRs and the practice of radiologic evaluation, were sent to the medical directors of all adult ICUs in the Netherlands. CXR strategies were compared between all academic and non-academic hospitals and between ICUs of different sizes. A comparison was made between the survey results obtained in 2006 and 2013.

Results. Of the 83 ICUs that were contacted, 69 (83%) responded to the survey. Only 7% of responding ICUs were currently performing daily routine CXRs for all patients, and 61% of the responding ICUs said never to perform CXRs on a routine basis. A daily meeting with a radiologist is an established practice in 72% of the responding ICUs and is judged to be important or even essential by those ICUs. The therapeutic efficacy of routine CXRs was assumed by intensivists to be lower than 10% or to be between 10 and 20%. The efficacy of on-demand CXRs was assumed to be between 10 and 60%. There is a consensus between intensivists to perform a routine CXR after endotracheal intubation, chest tube placement or central venous catheterization.

Conclusion. The strategy of daily routine CXRs for critically ill and mechanically ventilated patients has turned from a common practice in 2006 to a rare current practice. Other routine strategies and an on-demand only strategy have become more popular. Intensivists still assume the value of CXRs to be higher than the efficacy that is reported in the literature.

BACKGROUND

Intensive care unit (ICU) patients frequently undergo chest radiographs (CXRs), on a routine basis, after a change in their clinical situation or directly after surgery. Several investigators have studied the clinical value of routine CXRs following central venous catheterization, endotracheal intubation, cardiac surgery, pulmonary surgery or chest tube placement and removal [1-18]. Other investigators have studied the value of daily routine CXRs in a mixed ICU population or in mechanically ventilated patients only [19-28]. The diagnostic and therapeutic efficacy of these routine radiographs is now known to be low [1-3; 6-10; 12-15; 17; 19-20; 22-25; 28]. Studies that compared a routine CXR strategy with an on-demand CXR strategy did not show any difference in outcome measures [29-34].

Despite these results, in 2006, Graat et al. showed that in a majority of intensive care units in The Netherlands, a daily routine CXR strategy was still common practice [35]. Intensivists at that time assumed a higher value of a daily CXRs than had been reported in the literature. Although a more restrictive CXR strategy seems safe, Ganapathy et al. stated in a more recent meta-analysis that study populations were small and the number of missed findings was not sufficiently evaluated [33]. Meanwhile the discussion regarding specific indications for CXRs in critically ill patients and the safety of abandoning routine CXRs is still ongoing. We performed a new survey among Dutch intensivists on their current chest radiography practice in order to study the influence of time and knowledge in relation to any changes in that practice.

METHODS

For our study, we selected all Dutch academic hospitals (related to a university medical school) and non-academic hospitals with an independent adult ICU department. A web-based questionnaire, deployed using the website www.thesistools.com, was sent to the medical staff of these ICUs by the end of April 2013. A reminder was sent after two weeks, four weeks and six weeks after the questionnaire was originally sent. All hospitals received 1 questionnaire, as it is currently common in our country to have 1 adult ICU center with a combined medical staff and a mixed patient population. For data analysis, we included all questionnaires that were answered within 8 weeks from the start of the study, with a response of more than 80%. The questionnaire we deployed was based on the questionnaire used previously in 2006 [35]. After confirming a specific hospital's response, this response was made anonymously. Additional re-

sponses from the same hospital were not included.

The survey contained questions regarding hospital and ICU characteristics, type of ICU patients, CXR strategies, indications for routine CXRs and the practice of radiologic evaluation. Regarding ICU size, only beds with the possibility of mechanical ventilation were taken into account. We asked the intensivists to judge the clinical value (therapeutic efficacy) of routine and on-demand CXRs and to judge the value of an established radiologic evaluation with a radiologist. We finally asked them to state some indications for routine CXRs.

CXR strategies were compared between all hospital, between academic and non-academic hospitals and between ICUs of different sizes. A comparison was made between the survey results from 2006 and 2013. Therapeutic efficacy was defined as the percent of CXR findings that resulted in a subsequent change in patient management.

Data analysis was performed using IBM SPSS Statistics 21.0 (IBM, Armonk, NY, USA). All variables were expressed as counts (%). Differences in CXR strategies between 2006 and 2013 were examined using Fisher's exact test.

RESULTS

A total of 83 hospitals with an adult ICU were selected for this study, and 69 hospitals (83%) responded to the web survey. The non-responders were one academic hospital and thirteen non-academic hospitals of limited size. The characteristics of the responding ICU departments are shown in Table 1. Only 10% of the responders were academic hospitals, while 90% of the institutions were non-academic. Most ICUs (58%) had between five and fifteen beds with the option of mechanical ventilation available, and 29% of ICUs had more than fifteen beds with the option of mechanical ventilation available. The most frequent number of fulltime intensivists available was one to five (46%) or five tot ten (36%). Cardiac surgery patients were admitted to 29% of the responding ICUs, and neurosurgical patients were admitted to 23% of the responding ICUs.

Of all hospitals, 39% practiced some kind of routine CXR strategy, but only 7% of ICUs obtained daily routine CXRs for all patients (Table 2). Some other ICUs only performed daily routine CXRs for mechanically ventilated patients (6%), patients in the first days of ICU admission (4%), all patients on certain fixed days of the week (3%) or for cardiothoracic surgery patients only (6%). Most ICU departments (61%) state that they never perform daily CXRs on a routine basis. A distinctive group seems to be the academic ICUs and largest non-academic ICUs, because 86% of the academic ICUs

and 75% of the ICUs with > 15 beds practice some kind of routine chest radiography strategy.

Table 3 presents a comparison of the survey results from 2006 and the results of the current study. The number of ICUs that used some kind of routine CXR strategy decreased from 63% to 39% from 2006 to 2013 (p=0.018). There was a decrease in the use of a daily routine CXR strategy for all ICU patients although this decrease was not significant (p=0.324). However, there was an important decrease in the use of a routine CXR strategy for mechanically ventilated patients (p<0.001). The frequency of other routine strategies and, in particular, of an on-demand only strategy increased from 2006 to 2013 (p=0.095 and p=0.018). There were no significant differences in the performance of routine CXRs after chest tube placement, endotracheal intubation, central venous catheterization, cardiopulmonary resuscitation or tracheostomy.

The practices of radiologic evaluation with a radiologist are shown in Table 4. The majority of ICUs had a daily established meeting with a radiologist, and this daily meeting was including the weekend for 28% of ICUs and on week days only for 44% of ICUs. Only 12% of the responding ICU departments never evaluate their CXRs in a specially arranged meeting. A daily radiological conference was considered essential by 46% of the ICU's and good for cooperation by 74% of the ICU's. The training purposes of a daily radiologic conference were considerd important by only 19% of the ICUs.

Table 5 shows the responding intensivits' assumed therapeutic efficacy values for CXRs performed routinely and CXRs performed on a special indication only (on-demand). The efficacy of routine CXRs was generally assumed to be lower than 10% or to be between 10% and 20%. The efficacy for on-demand CXRs was assumed to be obviously higher, somewhere between 10% and 60%.

There seems to be a consensus for the indication of a routine CXR after chest tube placement and central venous catheterization (Table 6). Other frequently suggested indications for CXRs are the diagnostic workups for the presence of a pneumothorax, pneumonia or adult respiratory distress syndrome (ARDS).

DISCUSSION

Our results show that a strategy of daily routine CXRs is performerd for all patients in only 7% of ICUs and for all mechanically ventilated patients in only 6% of ICUs, while 61% of the ICUs never perform CXRs on a routine basis. A daily meeting with a radiologist is an established practice in the majority of ICUs and is judged to be important or even essential. Our results are in line with the results of Lakhal et al. who did an obser-

vational day study in French ICUs in 2010 [36]. In their study population a daily routine CXR strategy was also practiced in 7% of ICUs, while 63% of ICUs never performed routine CXRs. Compared to the results of Graat et al. in 2006, there has been an obvious change in chest radiography strategies in Dutch ICUs. Then the majority of ICUs practiced a daily routine CXR strategy [35]. An on-demand only strategy and other more liberal routine strategies have become more common in recent years.

The indications for routine CXRs suggested by the responders in our survey are in general comparable to the indications suggested in the surveys performed by Graat et al. and Hejblum et al. [35; 36]. There is still consensus between intensivists regarding the importance of obtaining a CXR after endotracheal intubation, chest tube placement and central venous catheterization and for diagnostic workups for pneumonia, ARDS or pneumothorax. However, the indications for a routine CXR after intubation and central venous catheterization are not supported by the literature [1-3; 6]. There is no consensus that a routine CXR should be performed for all mechanically ventilated patients [35; 37].

Although our results, and the reduction in routine CXR strategies, suggest that intensivists seem to be aware of the limited clinical value of routine CXRs, they still assume this value to be higher than the efficacy that is reported in the literature [35]. This is also true for the clinical value of on-demand CXRs. In recent literature, the reported diagnostic efficacy for CXR small findings is between 30% and 65%, while the diagnostic efficacy for important findings and the therapeutic efficacy of CXRs are reported to be between 2% and 7% [22-4; 28]. Intensivists may assume a higher clinical value of CXRs due to the value of negative CXR findings, which has not been previously studied. The ability of CXR findings to exclude complications, certain clinical situations or the need for an intervention, probably has a clinical impact that is hard to study.

During the last decade, multiple studies have shown that an on-demand CXR strategy increases the diagnostic and therapeutic efficacy of CXRs in critically ill patients while subsequently reducing the number of CXRs and subsequent costs significantly. No difference in mortality, length of mechanical ventilation or length of ICU or hospital stay was found [29-34]. Kroner et al. found no change in the number of computed tomography (CT) or ultrasound studies performed by the department of radiology for ICUs that use an on-demand CXR strategy [34]. To our knowledge there are no studies regarding the impact of an on-demand CXR strategy on the number of ultrasound studies performed by intensivists or vice versa. A routine ultrasound examination of the pleura and pericardium performed by ICU physicians after cardiac surgery or before ICU discharge might further reduce the use routine CXR strategies.

However, completely abandoning routine CXRs for ICU patients is still under debate because the currently available studies did not evaluate the effect of missed findings, had low patient numbers did not rigorously assess possible harm [33]. More prospective studies need to be performed on the topic of missed findings, the clinical value of negative findings and the indications for CXRs in an on-demand only strategy, before a definitive conclusion can be drawn.

CONCLUSIONS

The strategy of daily routine CXRs for critically ill and mechanically ventilated patients has turned from being a common practice in 2006 to a rare current practice. Other routine strategies and an on-demand only strategy have become more popular. Intensivists still assume that the value of CXRs is higher than the efficacy reported in the literature.

Table 1. Hospital and ICU characteristics. (All hospitals, n=69)

Hospital type; n (%)	number of intensivists
Academic	7 (10)
Non-academic	62 (90)
ICU level; n (%)	
Level 1[1]	25 (36)
Level 2[2]	18 (26)
Level 3[3]	26 (38)
Number of ICU beds; n (%)	
< 5	9 (13)
5-15	40 (58)
> 15	20 (29)
Number of fulltime intensivists; n (%)	
1-5	32 (46)
5-10	25 (36)
11-20	12 (17)

ICU = Intensive Care Unit; n = Number
[1] Intensivist available in hospital, on weekdays during daytime, 2.7 fulltime ICU nurses per bed.
[2] Intensivist exclusively available for ICU, on 7 days a week during daytime, 3.5 fulltime ICU nurses per bed.
[3] Intensivist exclusively available for ICU, on 7 days a week during day and night, 4.2 fulltime ICU nurses per bed.

Table 2. Current CXR practice.

	Routine strategy	On-demand only
All Hospitals (n=69); n (%)	27 (39)	42 (61)
All patients	5 (7)	-
Patients on ventilation only	4 (6)	-
Certain fixed days a week	3 (4)	-
First days of admission only	2 (3)	-
Cardiothoracic surgery patients only	4 (6)	-
Other, not specified	9 (13)	-
Academic Hospitals (n=7); n (%)	6 (86)	1 (14)
Non-academic Hopitals (n=62); n (%)	21 (34)	41 (66)
ICU < 5 beds (n=9); n (%)	3 (33)	6 (67)
ICU 5-15 beds (n=40); n (%)	9 (22)	31 (78)
ICU > 15 beds (n=20); n (%)	15 (75)	5 (25)

CXR = Chest Radiograph; n = Number; ICU = Intensive Care Unit

Table 3. Comparison of CXR strategies between 2006 and 2013.

	2006 (n=41)	2013 (n=69)	p-value
Daily routine CXR strategy; n (%)	26 (63)	27 (39)	0.018
All patients	6 (15)	5 (7)	0.324
Mechanically ventilated patients	15 (37)	4 (6)	<0.001
Other daily routine strategy	5 (12)	18 (26)	0.095
On-demand only strategy; n (%)	15 (37)	42 (61)	0.018
Routine CXR after; n (%)			
Chest tube placement	40 (98)	68 (99)	1.000
Endotracheal intubation	31 (76)	53 (77)	1.000
CVL placement	34 (83)	52 (76)	0.475
CPR setting	24 (59)	40 (68)	1.000
Tracheostomy	24 (59)	30 (43)	0.168

CXR = Chest Radiograph; CVL = Central Venous Line; CPR = Cardiopulmonary Resuscitation

Table 4. Practice of radiologic evaluation. (All hospitals, n=69)

Radiologic conference; n (%)	
Daily	19 (28)
Daily except weekends	30 (44)
On request only	12 (17)
Never	8 (12)
Judged value of radiologic conference; n (%)	
Worthless	6 (9)
Essential	32 (46)
Good for cooperation	51 (74)
Required for training purpose	13 (19)

n = Number

Table 5. Assumed value of CXRs. (All hospitals, n=69)

Assumed therapeutic efficacy; n (%)	Routine CXR	On-demand CXR
< 10%	17 (25)	5 (7)
10-20%	11 (16)	21 (30)
20-30%	6 (9)	23 (33)
30-60%	3 (4)	17 (25)
> 60%	0 (0)	3 (4)
Not applicable	32 (46)	

CXR = Chest Radiograph; n = Number

Table 6. Suggested indications for which a CXR is deemed essential for diagnosis or assessment. (All hospitals, n=69)

Indication; n (%)	
Presence of ARDS	43 (62)
Presence of a pneumonia	47 (68)
Presence of a pneumothorax	53 (77)
Patients volume status	12 (17)
Correct position of CVL	64 (93)
Correct position of chest tube	66 (96)
Correct position of IABP	36 (52)

CXR = Chest Radiograph; n = Number; ARDS = Adult Respiratory Distress Syndrome; CVL = Central Venous Line; IABP = Intra Aortic Balloon Pump

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Chapter 3

Why intensivists want chest radiographs

M. Tolsma
P.H.J. van der Voort
N.J.M. van der Meer

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LETTER

Dear Editor.

We would like to contribute to the ongoing discussion regarding different chest radiograph (CXR) strategies in the intensive care unit (ICU). In their review and meta-analysis in a recent issue of Critical Care, Ganapathy and colleagues concluded that they found no harm associated with a restricted CXR strategy for ICU patients [1]. On the other hand, they stated that the safety of abandoning routine CXRs for ICU patients was still uncertain.

Several investigators, including one large multicenter randomized trial [2], confirmed that performing an on-demand CXR strategy instead of a daily routine CXR strategy decreased the total number of CXRs significantly and was accompanied by an increase in their diagnostic efficacy, but without any increase in adverse events or the use of other imaging studies. This leads to the question what the exact indications for on-demand CXRs in critically ill patients are. And might there be certain patient groups that may still benefit from routine CXRs?

Another interesting point of view is the impact of an on-demand CXR strategy on workflow and efficiency [3], where a number of issues still need to be addressed. For example, can certain ICU patients safely be transferred to the ward without performing a CXR before? What is the impact of 'negative' CXR findings on this workflow and on our personal clinical decision-making? And is it possibly more (cost) efficient for a radiology department to perform multiple routine CXRs during a morning round instead of performing several single CXRs during the day and night?

Our recent web study among Dutch intensivists showed that, nowadays, in line with the current evidence, a daily routine CXR strategy is used significantly less frequent than one decade ago [4]. However, surrogate routine strategies like a performing a routine CXR on certain fixed days a week or on the first days of admission only, have become more popular. Intensivists still assume the value of these CXRs to be higher than the efficacy that is reported in the literature and this might be due to the clinical value of negative findings, which has not been studied before. And most clinicians, including surgeons and consulting physicians, probably are used to the performance of CXRs for their ICU patients.

A lot of ICUs seem to have no clear protocol regarding specific indications for CXRs, and the least experienced ICU clinicians may request more CXRs. The importance of (negative) CXR findings on workflow, efficiency and clinical decision-making may be larger than is estimated. To further reduce the number of unnecessary CXRs safely, we recommend ICU departments to design a local protocol regarding their CXR indications. In addition, ideally, experienced intensivists should request these CXRs for mentioned reasons.

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Chapter 4

The clinical value of routine chest radiographs in the first 24 hours after cardiac surgery

M. Tolsma
A. Kröner
C.L.M. van den Hombergh
P.M.J. Rosseel
T.A. Rijpstra
H.A.J. Dijkstra
M. Bentala
M.J. Schultz
N.J.M. van der Meer

Anesthesia & Analgesia, January 2011

ABSTRACT

Background. Chest radiographs (CXRs) are obtained frequently in the intensive care unit (ICU). Whether these CXRs should be performed routinely or on clinical indication only is often debated. The aim of our study was to investigate the incidence and clinical significance of abnormalities found on routine postoperative CXRs in cardiac surgery patients and whether a restricted use of CXRs would influence the number of significant findings.

Methods. We prospectively included all consecutive patients who underwent cardiac surgery during a two-month period. Two or three CXRs were performed in the first 24 hours of ICU stay. After ICU admission and after drain removal, a clinical assessment was performed before a CXR was obtained. All CXR abnormalities were noted and it was also noted whether they led to an intervention. For the admission CXR and the drain removal CXR, a comparison was made between CXRs clinically indicated by the physician and those not clinically indicated.

Results. Two hundred fourteen patients were included. The majority of patients underwent coronary arterial bypass grafting (60%), heart valve surgery (21%), or a combination of these (14%). In total 534 CXRs were performed (2,5 per patient). Abnormalities were found on 179 CXRs (33,5%) and 13 CXR results led to an intervention (2,4%). The association between clinically indicated CXRs and the presence of CXR abnormalities was poor. For 32 (10%) of the 321 admission- and drain removal CXRs, clinical indications were stated by the physician beforehand. If these CXRs would not have been performed routinely, 68 abnormalities would have been missed, of which 5 led to an intervention.

Conclusions. Partial elimination of routine CXRs in the first 24 hours after cardiac surgery seems possible for the majority of patients, but it is limited by the insensitivity of clinical assessment in predicting clinically important abnormalities detectable by CXRs.

INTRODUCTION

Chest radiographs (CXRs) are frequently obtained routinely in intensive care unit (ICU) patients [1]. CXRs are also obtained routinely after interventions or surgical procedures. Several studies investigated whether a more restricted use of CXRs is safe for ICU patients. Obtaining CXRs on an on-demand instead of a routine basis may have several advantages, like a reduction in CXRs with false-positive results, lower costs and less irradiation to the patient. However, if important findings are missed, the more restricted use may possibly delay therapy and could therefore increase the length of ICU stay, raise the number of ICU readmissions, or even increase mortality.

Some previous studies conclude that CXRs should still be performed on a routine basis for ICU patients, because of the high incidence of new findings [2], the poor association with clinical examination [3], the high incidence of changes in therapy based on the CXR findings [4], and because it is probably more cost-effective to catch new findings at an early stage [5]. Other studies conclude that routine CXRs should be abandoned because of the low incidence of clinically important findings [6-9] or because of the high sensitivity of clinical examination for the more serious conditions diagnosed on CXRs [10]. Conflicting results also exist regarding the usefulness of routine CXRs after procedures like endotracheal intubation [11-12] or central venous catheter insertion [13-15].

Several investigators reported no difference in mortality rate, length of ICU stay, length of hospital stay or the number of ICU readmissions after the elimination of routine CXRs [9, 16-21]. Furthermore there are no indications that the reduction in CXRs was accompanied by a subsequent increase in the number of computed tomography and ultrasound studies [20]. As a result, changing the protocol led to a substantial costs reduction [22]. Despite this recent evidence, routine CXRs are still common practice in many ICU departments [23].

The majority of the mentioned studies refer to a general ICU population. Only one study refers to a post-cardiac surgery population [18]. Therefore the aim of this study was to investigate the incidence and clinical significance of abnormalities found on routine postoperative CXRs in cardiac surgery patients and whether a restricted use of CXRs would influence the number of significant findings. The postoperative care for cardiac surgery patients often includes 2 or 3 CXRs within the first 24 hours after surgery. The first CXR is obtained at ICU admission, a second on the morning of the first postoperative day, and eventually, a third CXR is performed after removal of pleural space drains. Our hypothesis is that a reduction in the number of CXRs to only 1 routine

CXR on the morning of the first postoperative day will not lead to a significant under-diagnosis of clinical significant abnormalities.

METHODS

This study was performed in a tertiary 24-bed closed format ICU, admitting medical, surgical and cardiothoracic surgical patients. The medical staff consisted of 16 intensivists and 8 residents in ICU medicine. The study protocol was approved by the local ethics committee. Informed consent was deemed not necessary since no interventions were applied to the patients.

We prospectively included all consecutive cardiothoracic patients who underwent cardiac surgery during a 2-month period. All patients were admitted to the ICU directly after surgery and a first CXR was then obtained (admission CXR, CXR 1). A second CXR was performed on the morning of the first postoperative day (postoperative day CXR, CXR 2) and if pleural space drains were present, a third CXR was performed after removal of these drains (drain removal CXR, CXR 3).

The admission CXR (CXR 1) and the drain removal CXR (CXR 3) were both preceded by a clinical investigation performed by an ICU physician. The attending physician was then asked whether the CXR was deemed necessary. This decision was based on (a) physical examination including auscultation of heart and lungs, (b) interpretation of the patients vital parameters, and (c) the results of the first arterial blood gas sample. In case the CXR was deemed necessary, it was marked 'clinically indicated', otherwise it was also obtained and marked 'not clinically indicated'. The postoperative day CXR (CXR 2) was not preceded by a clinical assessment because we preferred to perform this CXR on a routine basis, according to our hypothesis.

The first and second CXR were both included in the study for all patients, except when it was occasionally not performed due to ICU arrival in the morning (no CXR1) and early death of 1 patient (no CXR 2). The third CXR was only included when pleural space drains were removed within the first 24 hours after surgery.

Demographic data were collected for all patients. The mean age, mean number of CXRs per patient and the median duration of ICU and hospital stay were calculated. All CXRs were assessed by both a radiologist and an ICU physician. All CXR abnormalities were noted, and it was also noted whether an abnormality led to an intervention. Only new findings were analysed and abnormalities already present on the previous CXR were not considered again. The diagnostic efficacy (the number of abnormalities divided by the total number of CXRs) and therapeutic efficacy (the number of interventions based on CXR abnormalities divided by the total number of CXRs) were calculated for all three CXRs. The results of CXRs 1 and 3 were classified according to whether these CXRs were marked 'clinically indicated' or 'not clinically indicated' by the physician beforehand, and the association with the presence of CXR abnormalities was depicted. False-negatives, fals-positives, sensitivity and specificity were calculated. Findings which led to an intervention and which would have been missed if the latter CXRs were not performed routinely were noted seperately.

Data analysis was performed using SPSS version 17.0 (SPSS Inc., Chicago, IL) for Windows.

RESULTS

Two hundred fourteen successive post-cardiac surgery patients were included (Table 1). The mean age was 67 years and the majority of patients were men (74%). Most patients underwent coronary arterial bypass grafting (60%), heart valve surgery (21%), or a combination of these (14%). The median length of ICU stay was 1 day.

A total of 534 CXRs were performed (a mean of 2.5 per patient) of which the results are shown in Table 2. One hundred seventy nine abnormalities were found, resulting in an overall diagnostic efficacy of 33.5% for all CXRs. Pleural effusion, atelectasis, consolidation, a widened mediastinum and malposition of invasive devices were the most frequent abnormalities on CXRs 1 and 2. CXR 3 showed a low incidence of a widened mediastinum and pneumothorax. The overall therapeutic efficacy was 2.4%.

The association between the physician's answer to whether a CXR was clinically indicated beforehand and the results of these CXRs is depicted for the admission and drain removal CXRs in Table 3. The label 'clinically indicated' or 'not clinically indicated' had a sensitivity and specificity of respectively 19% and 93% for CXR 1 and 0% and 92% for CXR 3. If the admission and drain removal CXRs that were marked 'not clinically indicated' would not have been performed, a total of 68 abnormalities would have been missed. Five of these abnormalities led to an intervention (Table 4); respectively a change in endotracheal tube position in two cases, the start of diuretic therapy, a change in intra-aortic balloon pump (IABP) position and an ultrasound guided drainage of pleural effusion. None of these interventions were initiated by abnormalities on CXR 3. Only 32 (10%) of all 321 admission and drain removal CXRs were clinically indicated beforehand according to the physicians opinion. Therefore, when routine CXRs would not have been performed, a reduction of 289 CXRs would have occurred in a two-month period.

DISCUSSION

We found an overall diagnostic efficacy of 33,5% for all CXRs performed in the first 24 hours after cardiac surgery. Because the majority of findings did not lead to an intervention, the overall therapeutic efficacy was only 2.4%. These results correspond with the findings of studies referring to a general ICU population [2-3; 5-9; 17; 19]. In our study the association between clinically indicated CXRs and the presence of CXR abnormalities was poor. This also confirms previous results [3]. But although the value of a clinical examination for predicting CXR findings may be limited, this simple procedure can still identify some abnormalities that may lead to complications.

As mentionded above, several investigators have studied the effect of eliminating routine CXRs in a general ICU population [9; 16-22]. A recent multicentre cluster-randomized trial in a general mechanically ventilated ICU population found a 32% reduction in CXRs within the on-demand strategy group compared to the routine strategy group [21], and as in all previous studies comparing these strategies, they did not find any difference in secondary outcome measures. Mets et al. found comparable results in a population of post-cardiothoracic surgery patients [18]. However, they did not investigate the clinical consequence of the CXR abnormalities found, and neither study investigated what findings were missed in the on-demand strategy group.

In this study, we investigated the incidence and clinical significance of CXR abnormalities found by postoperative CXRs in cardiac surgery patients. We also investigated whether it will be possible to reduce the number of routine CXRs to only 1 in the first 24 hours of ICU stay. According to our study design, in which a routine CXR was performed in every case after clinical examination, no findings could be missed and special emphasis was placed at the clinical consequence of abnormalities found. Beforehand we aimed for elimination of routine CXRs 1 and 3, since CXR 1 is taken shortly after surgical closure of the chest and CXR 3 is taken shortly after CXR 2 following the limited risk procedure of pleural space drain removal. CXR 2 would then still be performed routinely since most of the patients will be transferred to the ward shortly after. However, our results show that clinically important abnormalities were found on 4.2% of CXRs 1 followed by another 1.9% of CXRs 2. Although it may not seem reasonable now to delay the first postoperative CXR, we did not investigate the possible consequence of treatment delay of the abnormalities we found. To perform a CXR just before transfer to the ward has a certain safety benefit, but if this is the first postoperative CXR, it will delay diagnosis of abnormalities already present shortly after surgery. The additive benefit of CXR 3 seems to be limited, although delaying CXR 2 until after pleural space drain removal can still ensure finding a rare pneumothorax.

Our study is limited by the fact that this is a single centre study. Since we only investigated the value of routine CXRs in the first 24 hours of ICU stay only we did not address the long term (>24 hours) safety issue of changing the CXR protocol.

For the majority of patients it seems reasonable to reduce the number routine CXRs in the first 24 hours of ICU stay, but the optimal timing of these CXRs remains unclear. A new on-demand strategy may lead to a substantial reduction in CXRs, but we also showed that clinical assessment only is not sufficient enough to identify those patients who are at risk for under-diagnosis in this new strategy. The risk/benefit ratio might be unfavourable in certain patient groups. A more detailed analysis of this topic is beyond the scope of this study and further studies are necessary to identify those categories of patients at risk to address the safety issue adequately.

Table 1. Baseline data of the postoperative cardiothoracic patients.

Patients, N	214
Age, mean ± SD	67 ± 10
Gender, male, N (%)	159 (74%)
Length of ICU stay, days, median [IQR]	1 [1-2]
Length of hospital stay, days, median [IQR]	7 [6-9]
Type of surgery, N (% of total)	
Arterial coronary bypass (CABG)	129 (60%)
Valve surgery	45 (21%)
Combination of CABG and valve surgery	30 (14%)
Other cardiac surgery	10 (5%)
Urgent surgery, N (%)	22 (10%)

N = number; SD = standard deviation; ICU = intensive care unit; IQR = interquartile range; CABG = coronary artery bypass graft.

Table 2. Number of CXRs with abnormalities and subsequent changes in therapy.

	Admission CXR (1)		Post operative day CXR (2)		Drain removal CXR (3)		Overall	
CXRs, N	213		213		108		534	
CXRs with abnormalities, N (%) (diagnostic efficacy)	75/213 (35%)		97/213 (46%)		7/108 (6%)		179/534 (33,5%)	
	Found	Therapy	Found	Therapy	Found	Therapy	Found	Therapy
Atelectasis	8	0	19	0	0	0	27	0
Widened Mediastinum	12	0	12	0	5	0	29	0
Consolidation	5	1	12	1	0	0	17	2
Pulmonary congestion	4	2	1	1	0	0	5	3
Pleural effusion	31	1	46	1	0	0	77	2
Pneumothorax	2	1	5	1	2	0	9	2
Malposition invasive devices	13	4	2	0	0	0	15	4
CXRs with abnormalities that changed therapy, N (%) (therapeutic efficacy)	9/213 (4,2%)		4/213 (1,9%)		0/108 (0%)		13/534 (2,4%)	

CXR = chest radiograph; N = number.

Table 3. Association between the physicians answer to whether a CXR was clinically indicated beforehand and the presence of abnormalities on these CXRs, for CXRs 1 and 3.

	Admission CXR (1)	Drain removal CXR (3)
CXRs, N	213	108
CXRs clinically indicated, N	24	8
CXRs without abnormalities (false-positives)	10/24 (42%)	8/8 (100%)
CXRs with abnormalities	14/24 (58%)	0/8 (0%)
CXRs not clinically indicated, N	189	100
CXRs without abnormalities	128/189 (68%)	93/100 (93%)
CXRs with abnormalities (false-negatives)	61/189 (32%)	7/100 (7%)
Sensitivity	19% (14/(14+61))	0% (0/(0+7))
Specificity	93% (128/(128+10))	92% (93/(93+8))

CXR = chest radiograph; N = number.

Table 4. Number of clinically important findings which would have been missed if routine CXRs were not performed, with subsequent interventions, for CXRs 1 and 3.

	Admission CXR (1)	Drain removal CXR (3)
CXRs, N	213	108
CXRs not clinically indicated, N	189	100
CXRs not clinically indicated, with abnormalities that led to an intervention, N	5	0
change of endotracheal tube position	2	-
start of diuretic therapy	1	-
ultrasound guided pleural effusion drainage	1	-
change of IABP position	1	-

CXR = chest radiograph; N = number; IABP = intra-aortic balloon pump.

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Chapter 5

Defining indications for selective chest radiography in the first 24 hours after cardiac surgery

M. Tolsma
T.A. Rijpstra
P.M.J. Rosseel
T.V. Scohy
M. Bentala
P.G.H. Mulder
N.J.M. van der Meer

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ABSTRACT

Objectives. In the intensive care unit (ICU) chest radiographs (CXRs) are obtained frequently routinely for postoperative cardiac surgery patients, despite the fact that the efficacy of routine CXRs is known to be low. We investigated the efficacy and safety of CXRs performed after cardiac surgery for specified indications only.

Methods. In this observational cohort study, we prospectively included all patients who underwent conventional major cardiac surgery by median sternotomy in the year 2012. On-demand CXRs could be obtained during the first postoperative period for specified indications only. A routine control CXR was performed on the morning of the first postoperative day for all patients who had not undergone a CXR prior to that time. The diagnostic and therapeutic efficacy values were calculated for all CXRs. Differences in findings were tested using Fisher's exact test or the chi-square analysis.

Results. A total of 1102 consecutive cardiac surgery patients were included in this study. The diagnostic efficacy of CXRs for major abnormalities was higher for the postoperative on-demand CXRs (n=301, 27%) than for the routine CXRs taken the morning after surgery (n=801, 73%)(6.6% vs. 2.7%, p=0.004). The therapeutic efficacy was higher for the on-demand CXRs, whereas the need for intervention after the next morning routine CXRs was limited to 5 patients (4.0% vs. 0.6%, p<0.001). None of these patients experienced a major adverse event.

Conclusions. Defining clear indications for selective CXRs following cardiac surgery is effective and seems to be safe. This approach may significantly reduce the total number of CXRs performed, and will increase their efficacy.

INTRODUCTION

Chest radiographs (CXRs) are obtained frequently and routinely for intensive care unit (ICU) patients, on a daily basis and after surgery or certain other procedures. Multiple investigators have studied the clinical value of routine CXRs following central venous catheterization, endotracheal intubation and chest tube placement or removal [1-12]. Others have studied the value of daily routine CXRs in a mixed ICU population or in mechanically ventilated patients only [13-21]. The diagnostic and therapeutic efficacy of all of these routine CXRs has been reported to be low [1-3; 6-9; 11; 13-14; 16-19; 21].

Investigators comparing a routine CXR strategy with an on-demand CXR strategy were not able to show any difference in outcome measures [22-28]. Although those studies indicated that a more restrictive CXR strategy should be safe, a more recent meta-analysis by Ganapathy and colleagues stated that, in those studies, the confidence intervals were wide, and the study populations were small. In addition, they asserted that the potential harm and missed findings were not assessed rigorously enough [26]. Meanwhile, the discussion regarding specific indications for CXRs in critically ill patients and the safety of abandoning routine CXRs is still ongoing.

In agreement with the results of studies on this topic in a general ICU population, the clinical value of routine chest radiographs after cardiac surgery is also known to be low [29-32]. Despite these findings, our recent web survey of Dutch intensivists revealed that the strategy of daily routine CXRs is a rare practice nowadays, with the exception of routine CXRs for postoperative cardiac surgery patients [33]. Abandoning routine CXRs after cardiac surgery may be safe only when patients at risk are identified and certain indications for CXRs are stated.

In 2011, we changed the protocol for CXRs after cardiac surgery in our department. Our former policy was to obtain routine CXRs for all postoperative cardiac surgery patients: at the moment of ICU arrival; on the morning of the first postoperative day; and after chest tube removal. We previously reported that the clinical value of CXRs using this strategy and the number of subsequent interventions were low [32]. With the new protocol, a CXR in the direct postoperative period is only performed for certain indications. A routine CXR on the first postoperative morning is still performed for all patients unless an on-demand CXR has been performed shortly before.

Our aim was to study the diagnostic and therapeutic efficacy of this new CXR strategy, performing CXRs after cardiac surgery for specified indications only. Our hypothesis was that the diagnostic efficacy of these postoperative CXRs, performed on a specified indication, would be higher. In addition, we expected that the diagnostic

efficacy of the routine CXRs, taken the morning after surgery for patients who did not meet any special indication, would be low.

METHODS

The study protocol was approved by the local ethics review board (at Amphia Hospital), and the need for written informed consent was waived, because no interventions were conducted with the patients, apart from those that were part of the usual and current local practice. This prospective, observational, single-center study was performed in a tertiary center, 24-bed, closed format ICU that admits medical, surgical, and cardiac surgery patients. The medical staff of this ICU consisted of 12 intensivists and 8 ICU residents. All patient data were collected anonymously.

We prospectively included all consecutive patients who underwent conventional major cardiac surgery by median sternotomy in the year 2012. All patients were admitted to the ICU directly after surgery. According to our new strategy, a direct postoperative CXR upon ICU arrival was performed routinely only for certain specified indications (Table 1). These indications were chosen to confirm the correct positioning of the intra-aortic balloon pump (IABP) and to rule out a pneumothorax or hemothorax after difficult central venous catheterization. Furthermore, a CXRs could be obtained throughout the first postoperative period, according to other specified indications (Table 1) determined by an ICU physician, after an assessment that included interpretation of the patient's vital parameters, the results of an arterial blood gas sample, and auscultation of the heart and lungs. For all patients who did not undergo a CXR before the morning of the first postoperative day, a routine control CXR was performed at that time.

Demographic data and perioperative characteristics were collected for all patients. The mean age of patients and the mean duration of the ICU stays were calculated. All CXRs were assessed by both a radiologist and an ICU physician. The CXR findings were classified according to the overview presented in Table 2 and were divided into minor findings and major findings. Only new findings were analysed, and abnormalities already present on a preoperative CXR were not taken into consideration for this study.

All CXR abnormalities were noted and categorized. An additional note was made if a major abnormality led to a subsequent intervention. Possible interventions were: chest tube placement, repositioning of invasive devices, diuretic therapy, echocardiography, and re-operation. The total numbers and fractions of CXRs that showed any findings, minor findings only, major findings, and findings that led to a subsequent intervention were calculated. The diagnostic efficacy (the number of abnormalities divided by the total number of CXRs) and therapeutic efficacy (the number of interventions based on CXR abnormalities divided by the total number of CXRs) were calculated. All major findings were noted separately, whether or not they led to an intervention.

The data analysis was performed using IBM SPSS Statistics v21.0 for Windows (SPSS Inc, Chicago, Ill). Differences in the percentages of findings and interventions between the on-demand CXRs, versus the routine CXRs on the first postoperative morning, were tested using Fisher's exact test or the chi-square analysis when appropriate. To account for multiple testing, more stringent criteria were used than the usual 0.05 significance level. A p-value below 0.01 was considered to denote a statistically significant difference by intervention or finding.

RESULTS

Table 3 shows the baseline characteristics of the study population. A total of 1102 consecutive cardiac surgery patients were included in the study. Most patients (73%) were men, and the mean patient age was 69 ± 9 years. The mean length of ICU stay was 2.0 nights. Most patients underwent a coronary artery bypass grafting (CABG), valve surgery or a combination of the two.

For 301 patients (27%), a CXR was performed on-demand, at ICU admission, or at some point during the first postoperative period. The remaining 801 patients (73%) had a routine control CXR taken on the morning of the first postoperative day. Table 4 shows the number and type of CXRs specified per procedure. Notably, the routine control CXR group consisted of almost two-thirds of CABG patients (65%), because 79% of the CABG patients did not meet the criteria for an an-demand CXR before the next morning.

The values for various CXR findings are presented in Table 5. All CXRs had a comparable diagnostic efficacy for minor abnormalities, of approximately 45% (p=0.22). The diagnostic efficacy for major abnormalities was clearly higher for the on-demand CXR group than for the group who had routine CXRs on the next morning (6.6% versus 2.7%) (p=0.004). The therapeutic efficacy was 4.0% for the on-demand CXRs, whereas the routine CXRs had a therapeutic efficacy of only 0.6% (p<0.0005).

Table 6 shows an overview of all the major abnormalities found, and the frequency of subsequent diagnostic or therapeutic interventions. For the on-demand CXRs, the most frequent reasons for an intervention were: a hemothorax (n=3), a widened mediastinum (n=3), malposition of invasive devices (n=3) or a pneumothorax (n=2). Common

interventions based on the CXR results were chest tube placement, re-operation, re-positioning of an invasive device and echocardiography. Only 5 of the 23 major abnormalities found on the routine CXRs, taken on the first postoperative morning, required an intervention. In four patients a chest tube was placed because of a pneumothorax (n=3) or large pleural effusion (n=1). In one patient an echocardiography was performed after the presence of a widened mediastinum detected on the routine CXR. Only a small amount of pericardial effusion was found in this case, for which no intervention was necessary. These complications had no effect on ICU length of stay. Four patients left the ICU on the same day and the fifth patient was kept 2 days longer for other reasons. All five patients were discharged from the ICU and from the hospital in good condition.

DISCUSSION

Our results show that the therapeutic and diagnostic efficacy of on-demand CXRs that are performed directly or shortly after cardiac surgery is clearly higher when specific indications are stated. The efficacy of a routine CXR taken on the first postoperative morning, for patients without a prior direct indication for a CXR, was very low.

The high diagnostic efficacy for minor findings (45%) is in agreement with the findings of previous studies [21]; and similarly a higher diagnostic efficacy was found for major findings (7% compared to 3%) when CXRs were obtained on-demand rather than routinely [17-18; 21]. The generally low therapeutic efficacy of CXRs that we found is in agreement with previous findings as well [16-18; 21]. However, more importantly, the therapeutic value of our routine control CXR taken on the first postoperative morning (0.6%) was far lower than reported in previous, indicating that the number of important findings missed by the on-demand CXRs was minimal.

According to our results, the practice of taking a routine CXR directly after cardiac surgery can be safely discontinued, as long as clear indications are stated for when patients need a direct postoperative CXR at ICU arrival, or an on-demand CXR throughout the first postoperative period. This strategy will significantly reduce the total number of CXRs performed for cardiac surgery patients. In our department, the number of immediate postoperative CXRs was reduced by 73% (801 CXRs in one year, with a total cost savings of approximately $ 40.000). The control CXRs taken on the first postoperative morning indicated that only a minimal number of important findings were missed using this strategy, and that an intervention after this type of routine CXR was rare (0.6% of patients). The findings that were revealed on these CXRs are unlikely to have caused

any obvious clinical problems in the first postoperative period; thus, the delay in treatment until the next morning as a result of not performing a routine CXR at ICU arrival will probably not harm these patients. All five patients were discharged from the ICU within a short period, and no major adverse events occurred.

Furthermore, if correct indications are stated, the relevance of performing a routine CXR at all may be questionable; however, not doing so may conflict with our need for reassurance of the safety of our patients when they are transferred to the ward. Previously, we additionally showed a poor correlation between physical examination and CXR findings [32, 34], and the few major findings on the control CXRs taken on the first postoperative morning were not otherwise clinically identified.

We suggest performing a direct postoperative CXR when an intra-aortic balloon pump was placed or when central venous catheterization was problematic. In addition, an on-demand CXR can be performed during the first postoperative period, when certain hemodynamic or respiratory problems are present. For now, to perform a routine CXR on the first postoperative morning seems reasonable for patients who did not have a CXR previously in the postoperative period. More research on the safety of completely abandoning routine postoperative CXRs, for example in CABG patients, is necessary. Bedside chest ultrasound by ICU physicians may be a promising alternative [34-35].

Our study is limited by the fact that it was a single centre study and was performed according to an already existing protocol. In addition, we used an observational cohort study design without randomization or blinding. On the other hand, this design allowed us to evaluate so called 'missed findings', for the whole cohort, using a routine control CXR on the first postoperative morning. The study population was large, and clearly defined CXR indications were stated.

CONCLUSION

Defining clear indications for selective CXRs following cardiac surgery is effective and seems to be safe. This approach may significantly reduce the total number of CXRs performed, and will increase their efficacy.

Table 1. Established indications for an on-demand chest radiograph.

At ICU arrival:
Difficult CVL or PAC placement [1]
IABP placement
BMI < 20
During the first postoperative period:
Abnormal auscultation [2]
Poor oxygenation [3]
Persistent hypercapnia [4]
High ventilation pressures [5]
Persistent air leakage from chest tube(s)
Subcutaneous emphysema
Hemodynamic instability [6]
Suspicion of cardiac tamponade [6]

CVL = Central Venous Line; PAC = Pulmonary Artery Catheter; IABP = Intra-Aortic Balloon Pump; BMI = Body Mass Index.
[1] >2 attempts, site change, or air withdrawal
[2] Asymmetric breath sounds or severe rhonchi and/or crepitations
[3] PaO2/FiO_2 <200 mmHg
[4] $PaCO_2$ >50 mmHg
[5] Peak pressure > 30 cm H_20 at tidal volume 6-8 ml/kg ideal body weight
[6] Cardiac index < 2.0 L/min/m², pulsus paradoxus or unexplained hypotension

Table 2. Classification of radiologic findings.

Minor findings [1]	Major findings [2]
Little pleural effusion	Severe pleural effusion
Small atelectasis	Large atelectasis
Little pulmonary congestion	Severe pulmonary congestion
Small consolidation	Large consolidation
	Malposition of invasive devices
	Widened mediastinum
	Large subcutaneous emphysema
	Haemothorax
	Pneumothorax
	Pneumomediastinum
	Pneumopericardium
	Free air under diaphragm

[1] Involvement of less than 1 lobe and/or judged 'normal postoperative'
[2] Involvement of 1 lobe or more and/or judged 'no normal postoperative finding'

Table 3. Baseline data of the study population and procedures. (Number (proportion in%))

Patients	1102 (100)
Gender, male	809 (73)
Age, years, mean ± SD	69 ± 9
Length of ICU stay in days, mean (range)	2.0 (1-66)
Length of ICU stay 1 day	847 (77)
Procedures	
CABG	655 (59)
CABG with valve surgery	177 (16)
CABG with rhythm surgery	21 (1.9)
Valve surgery	140 (13)
Valve surgery with aortic surgery	42 (3.8)
Valve surgery with rhythm surgery	32 (2.9)
Aortic surgery	24 (2.2)
Other surgery	11 (1.0)

SD = Standard Deviation; ICU = Intensive Care Unit; CABG = Coronary Artery Bypass Graft.

Table 4. First obtained chest radiographs specified per procedure. (Number (row proportion in%))

	On-demand	Next morning
CABG, n=655	137 (21)	518 (79)
CABG and valve surgery, n=177	66 (37)	111 (63)
CABG and rhythm surgery, n=21	9 (43)	12 (57)
Valve surgery, n=140	48 (34)	92 (66)
Valve and aortic surgery, n=42	16 (38)	26 (62)
Valve and rhythm surgery, n=32	8 (25)	24 (75)
Aortic surgery, n=24	12 (50)	12 (50)
Other surgery, n=11	5 (45)	6 (55)
Total, n=1102	301 (27)	801 (73)

n = Number; CABG = Coronary Artery Bypass Graft.

Table 5. Chest radiograph findings and subsequent interventions. (Number (column proportion in %))

	On-demand	Next morning	Total	p-value
	n = 301	n = 801	n = 1102	
Any finding	147 (49)	393 (49)	540 (49)	1.00
Minor findings only	127 (42)	371 (46)	498 (45)	0.22
Major findings	20 (6,6)	22 (2,7)	42 (3,8)	0.004
Subsequent interventions	12 (4,0)	5 (0,6)	17 (1,5)	<0.001

n = Number.

Table 6. Specific major findings and number of interventions. (Number)

	On-demand CXR		Next morning CXR	
Finding	Found	Intervention	Found	Intervention
Severe pleural effusion	1	1	1	1
Large atelectasis	1	1	1	0
Severe pulmonary congestion	0	0	1	0
Malposition invasive devices	6	3	4	0
Widened mediastinum	7	3	6	1
Haemothorax	3	3	0	0
Pneumothorax	2	2	8	3
Pneumopericardium	0	0	2	0
Free air under diaphragm	1	0	0	0
Total[1]	21	13	23	5

CXR = Chest Radiograph.
[1] The total number of major findings and interventions may be higher in this table than in previous tables because some CXRs had more than 1 major finding.

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Chapter 6

The value of routine chest radiographs after minimally invasive cardiac surgery: an observational cohort study

M. Tolsma
M. Bentala
P.M.J. Rosseel
B.M. Gerritse
H.A.J. Dijkstra
P.G.H. Mulder
N.J.M. van der Meer

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ABSTRACT

Background. Chest radiographs (CXRs) are obtained frequently in postoperative cardiac surgery patients. The diagnostic and therapeutic efficacy of routine CXRs is known to be low and the discussion regarding the safety of abandoning these CXRs after cardiac surgery is still ongoing. We investigated the value of routine CXRs directly after minimally invasive cardiac surgery.

Methods. We prospectively included all patients who underwent minimally invasive cardiac surgery by port access, ministernotomy or bilateral video-assisted thoracoscopy (VATS) in the year 2012. A direct postoperative CXR was performed on all patients at ICU arrival. All CXR findings were noted, including whether they led to an intervention or not. The results were compared to the postoperative CXR results in patients who underwent conventional cardiac surgery by full median sternotomy over the same period.

Main Results. A total of 249 consecutive patients were included. Most of these patients underwent valve surgery, rhythm surgery or a combination of both. The diagnostic efficacy for minor findings was highest in the port access and bilateral VATS groups (56% and 63% versus 28% and 45%) ($p<0.005$). The diagnostic efficacy for major findings was also higher in these groups (8.9% and 11% versus 4.3% and 3.8%) ($p=0.010$). The need for an intervention was most common after minimally invasive surgery by port access, although this difference was not statistically significant ($p=0.056$).

Conclusions. The diagnostic efficacy of routine CXRs performed after minimally invasive cardiac surgery by port access or bilateral VATS is higher than the efficacy of CXRs performed after conventional cardiac surgery. A routine CXR after these procedures should still be considered.

INTRODUCTION

Chest radiographs (CXRs) are obtained frequently for intensive care unit (ICU) patients, on a routine basis, after a change in clinical situation or after surgery and other certain procedures. Multiple investigators have studied the clinical value of routine CXRs following central venous catheterization, endotracheal intubation and chest tube placement or removal [1-12]. Others have studied the value of daily routine CXRs in a mixed ICU population or in mechanically ventilated patients only [13-22]. The diagnostic and therapeutic efficacy of these routine CXRs is known to be low [1-3; 6-9; 11; 13-14; 16-19; 22]. Investigators comparing a routine CXR strategy with an on-demand CXR strategy were not able to show any difference in outcome measures [23-29], but a more recent meta-analysis by Ganapathy et al. indicated that study populations were small and that eventually missed findings in a restrictive strategy were not evaluated frequently enough [27]. Moreover, the discussion regarding specific indications of CXRs in critically ill patients and the safety of abandoning routine CXRs is still ongoing [25-27].

In accordance with the results of general studies on this topic, the clinical value of routine chest radiographs after cardiac surgery is reported to be low [30-34]. Abandoning routine CXRs in this population may only be safe when patients at risk are identified and certain indications of CXRs are stated. Minimally invasive cardiac surgery patients represent a population that might benefit from routine CXRs after surgery. Minimally invasive cardiac surgery has become increasingly popular over the past decade and is currently safe and effective [35-37]. Surgical access is obtained by (antero)lateral thoracotomy (port access), video-assisted thoracoscopy (VATS), mini-sternotomy or a parasternal approach. The procedures involved concern mainly valve surgery and rhythm surgery. The aims of minimally invasive surgery are to reduce blood loss, the number of reoperations, postoperative pain and the length of ICU stay and to promote a quick recovery and provide a cosmetically better result [35-38]. To our knowledge, there are no reports on CXR findings after minimally invasive cardiac surgery. Hypothetically, there are some findings that can be diagnosed by a postoperative CXR. These results might be related to the place of surgical access (pneumothorax, subcutaneous emphysema), temporary one lung ventilation technique (atelectasis), less surgical field visualization and hemostasis (haemothorax) or the need for invasive device placement (pulmonary artery catheter, temporary transvenous pacing wire). We performed a study on the efficacy of CXRs obtained directly after minimally invasive cardiac surgery.

METHODS

This prospective, observational, single-center study was performed on a tertiary 24-bed closed format ICU, admitting medical, surgical and cardiothoracic surgical patients. The medical staff consisted of 12 intensivists and 8 residents in ICU medicine. The study protocol was approved by the local ethics committee of the Amphia Hospital (AMOA; Adviescommissie Mensgebonden Onderzoek Amphia, mr. F. de Haan). This is the hospital where the study was conducted. The need for informed consent was waived because no interventions were applied to the patients apart from the common and current local practice. All patient data were obtained anonymously.

The study population was a part of another prospective study on CXR findings in all cardiosurgical patients admitted in the year 2012. We selected all consecutive patients who underwent minimally invasive cardiac surgery during this year, concerning patients for valve surgery, rhythm surgery or a combination of both. The patients were divided by the type of surgical access; port access, mini-sternotomy or bilateral VATS. All patients who underwent cardiac surgery by conventional full median sternotomy over the same period were used as a control group. Patients were admitted to the ICU directly after surgery. For all minimally invasive surgery patients, a CXR was obtained routinely at ICU arrival. For patients who underwent conventional surgery, a CXR was performed on-demand postoperative or routinely on the morning of the first postoperative day.

Demographic data and surgery characteristics were collected for all patients. The mean age and the median duration of ICU stay were calculated. All CXRs were assessed by both a radiologist and an ICU physician. CXR findings were classified according to the overview presented in Table 1 and were divided into minor findings and major findings. Only new findings were incorporated into analysis, and abnormalities already present on a preoperative CXR were not taken into consideration again.

All CXR abnormalities were noted. For major abnormalities it was also noted whether this abnormality led to an intervention. Possible interventions were chest tube placement, reposition of invasive devices, diuretic therapy, echocardiographic assessment and re-operation. The proportion of CXRs that showed minor and major findings was calculated, as was the proportion of CXRs with findings that led to a subsequent intervention. The diagnostic efficacy (the number of abnormalities divided by the total number of CXRs) and therapeutic efficacy (the number of interventions based on CXR abnormalities divided by the total number of CXRs) were also calculated. Finally, the CXR results of minimally invasive cardiac surgery patients were compared to the postoperative CXR results for patients who underwent cardiac surgery by conventional median sternotomy in the same period.

Data analysis was performed using IBM SPSS Statistics v21.0 for Windows. Differences in the percentages of findings and interventions were tested using Fisher's exact test. Other differences were tested using a two sample t-test or a Mann Whitney test where appropriate. A p-value below 0.05 was used to denote significance.

RESULTS

Table 2 shows the baseline characteristics of the study population. A total of 249 consecutive patients who underwent minimally invasive cardiac surgery by port access (n=124), mini-sternotomy (n=69) or bilateral VATS (n=56) were included. Most of these patients underwent valve surgery, rhythm surgery or a combination of both. Their CXR results were compared to the CXR results of 1102 patients who underwent conventional cardiac surgery in the same period. The most frequent procedure in this population was coronary artery bypass grafting (CABG) eventually combined with valve surgery or rhythm surgery. Patients who had cardiac surgery by port access or mini-sternotomy were less frequently male (55% and 49% compared to 73%) (p<0.005). Patients in the bilateral VATS group were younger (61±8 years compared to 69±9 years) (p<0.005). The mean length of ICU stay was shorter for all minimally invasive surgery groups when compared to that of the conventional cardiac surgery group (1.6, 1.5 and 1.1 days compared to 2.0 days) (p=0.007).

Table 3 shows a comparison of the diagnostic and therapeutic efficacies for CXRs performed after the different types of minimally invasive cardiac surgery and CXRs performed after conventional cardiac surgery. The diagnostic efficacy for minor findings was highest in the port access and bilateral VATS groups (56% and 63% compared to 28% and 45% in the mini-sternotomy and conventional surgery groups)(p<0.005). The diagnostic efficacy for major findings was also higher in the port access and bilateral VATS groups (8.9% and 11% compared to 4.3% and 3.8%) (p=0.010). The need for an intervention was most common after minimally invasive surgery by port access (4.8% of cases compared to 1.5% of cases after conventional surgery), although this difference was not statistically significant (p=0.056).

An overview of minor postoperative CXR findings is shown in Table 4. Pleural effusion, atelectasis and consolidation were observed more frequent after minimally invasive surgery by port access and bilateral VATS (p=0.019, p<0.005 and p<0.005), whereas pleural effusion and atelectasis were observed less frequently in the mini-sternotomy

group. Minor pulmonary congestion was observed significantly more frequently in the bilateral VATS group (p<0.005).

The major findings are presented in Table 5. The values shown are small, and only severe pulmonary congestion, large consolidation and large subcutaneous emphysema were observed statistically more frequently in the port access or bilateral VATS groups (p=0.013, p=0.024 and p=0.016). A pneumothorax, a haemothorax and malposition of invasive devices were also observed more frequently in all minimally invasive surgery groups, although this finding was not significant.

DISCUSSION

We observed that routine CXRs obtained after minimally invasive cardiac surgery by port access or bilateral VATS have a higher diagnostic value than CXRs performed after cardiac surgery by mini-sternotomy or conventional full median sternotomy. The high diagnostic efficacy for minor findings in all groups (40-60%) is comparable to the results reported in previous studies for cardiac surgery patients and studies performed in a general ICU population [22; 33]. We observed diagnostic efficacies of 8.9% and 11% for major findings after minimal invasive cardiac surgery by port access and bilateral VATS, which is clearly higher than what has been observed in more recent studies on the efficacy of chest radiographs after conventional cardiac surgery or for critically ill patients in generally [18; 31; 33]. A low therapeutic efficacy (1% to 4%) does correspond with previous findings [16; 18; 33]. We only observed a higher therapeutic value for CXRs after cardiac surgery by port access (4.8%).

The difference between patients who underwent minimally invasive cardiac surgery by port access or bilateral VATS and other cardiosurgical patients, as mentioned above, most likely be related to the complications of these surgical procedures. We were able to confirm a more frequent presence of atelectasis following a one lung ventilation technique. In addition, although not statistically significant, we did observe the relatively frequent presence of a pneumothorax, haemothorax and malposition of invasive devices after minimally invasive procedures. These results may be related to the place of surgical access, difficult hemostasis and the need for invasive device placement.

Because the discussion regarding the indications of CXRs in ICU patients and the specific clinical situations in which routine CXRs should still be performed is still ongoing, our results may be of interest. In our opinion, and in agreement with our findings, there is still a place for routine CXRs directly after minimally invasive cardiac surgery by port access or bilateral VATS. This is in contradiction to patients after uncomplicated conventional cardiac surgery or minimally invasive surgery by mini-sternotomy.

Our study is limited by the fact that it was a single-center study and that it was performed according to a routine CXR strategy protocol. A postoperative CXR was performed anyway for every patient. The study is also limited by the fact that we used an observational cohort study design without randomization or blinding. On the other hand, according to our design, no findings could be missed and the frequency of eventual subsequent interventions was evaluated.

CONCLUSION

Routine CXRs performed after minimally invasive cardiac surgery by port access or bilateral VATS have a higher diagnostic efficacy than CXRs performed after cardiac surgery by mini-sternotomy or conventional full median sternotomy. A routine CXR after these procedures should still be considered.

Table 1. Classification of radiologic findings.

Minor findings [1]	Major findings [2]
Minimal pleural effusion	Severe pleural effusion
Small atelectasis	Large atelectasis
Minimal pulmonary congestion	Severe pulmonary congestion
Small consolidation	Large consolidation
	Malposition of invasive devices
	Widened mediastinum
	Large subcutaneous emphysema
	Haemothorax
	Pneumothorax
	Pneumomediastinum
	Pneumopericardium
	Free air under diaphragm

[1] Involvement of less than one lobe, and/or judged 'normal postoperative'
[2] Involvement of one lobe or more, and/or judged 'no normal postoperative finding'

Table 2. Baseline data of the study population and procedures, divided by type of surgical access.

	PA	MS	BV	CS	p
Patients, n	124	69	56	1102	
Gender, male, n (%)	68 (55)	34 (49)	41 (73)	809 (73)	<0.005
Age, years, mean ± SD	68 ± 10	69 ± 12	61 ± 8	69 ± 9	<0.005
Length of ICU stay, days, mean (range)	1.6 (1-9)	1.5 (1-20)	1.1 (1-4)	2.0 (1-66)	0.007
Length of ICU stay 1 day, n (%)	93 (75)	63 (91)	53 (95)	847 (77)	<0.005
Procedures; n (%)					
CABG	-	-	-	655 (49)	<0.005
CABG with valve surgery	-	-	-	177 (13)	<0.005
CABG with rhythm surgery	-	-	-	21 (2)	0.345
Valve surgery	78 (63)	69 (100)	-	140 (13)	<0.005
Valve surgery with aortic surgery	-	-	-	42 (4)	0.016
Valve surgery and rhythm surgery	43 (35)	-	-	32 (3)	<0.005
Aortic surgery	-	-	-	24 (2)	0.230
Rhythm surgery	-	-	56 (100)	-	<0.005
Other surgery	3 (2,4)	-	-	11 (1)	0.389

PA = Port Access; MS = Mini-sternotomy; BV = Bilateral Video Assisted Thoracoscopy; CS = Conventional Sternotomy; n = Number; SD = Standard Deviation; ICU = Intensive Care Unit; IQR = Interquartile Range; CABG = Coronary Artery Bypass Graft; VATS = Video Assisted Thoracoscopy

Table 3. Comparison of diagnostic and therapeutic CXR values between different types of surgery.

	PA	MS	BV	CS	p
	(n=124)	(n=69)	(n=56)	(n=1102)	
CXRs with any finding, n (%)	80 (65)	22 (32)	41 (73)	540 (49)	<0.005
CXRs with minor findings only, n (%)[1]	79 (56)	19 (28)	35 (63)	498 (45)	<0.005
CXRs with major findings, n (%)[1]	11 (8.9)	3 (4.3)	6 (11)	42 (3.8)	0.010
CXRs with subsequent intervention, n (%)[2]	6 (4.8)	0 (0)	0 (0)	17 (1.5)	0.056

CXR = Chest Radiograph; PA = Port Access; MS = Mini-sternotomy; BV = Bilateral Video Assisted Thoracoscopy; CS = Conventional Sternotomy; n = Number
[1] Diagnostic efficacy
[2] Therapeutic efficacy

Table 4. Minor CXR findings.

	PA	MS	BV	CS	p
	(n=124)	(n=69)	(n=56)	(n=1102)	
Finding; n (%)					
Pleural effusion	22 (18)	3 (4.3)	12 (21)	171 (16)	0.019
Atelectasis	36 (29)	6 (8.7)	22 (39)	257 (23)	<0.005
Pulmonary congestion	12 (9.7)	11 (14)	19 (34)	173 (16)	<0.005
Consolidation	19 (15)	4 (5.8)	10 (18)	63 (5.7)	<0.005

PA = Port Access; MS = Mini-sternotomy; BV = Bilateral Video Assisted Thoracoscopy; CS = Conventional Sternotomy; CXR = Chest Radiograph; n = Number

Table 5. Major CXR findings.

	PA	MS	BV	CS	p
	(n=124)	(n=69)	(n=56)	(n=1102)	
Finding; n (%)					
Large pleural effusion / haemothorax	2 (1.6)	1 (1.4)	0 (0)	5 (0.5)	0.204
Large atelectasis	0 (0)	0 (0)	0 (0)	2 (0.2)	1.000
Severe pulmonary congestion	2 (1.6)	0 (0)	1 (1.8)	1 (0.1)	0.013
Large consolidation	2 (1.6)	0 (0)	0 (0)	0 (0)	0.024
Malposition invasive devices	3 (2.4)	2 (2.9)	1 (1.8)	10 (0.9)	0.104
Widened mediastinum	1 (0.8)	0 (0)	2 (3.6)	13 (1.2)	0.299
Large subcutaneous emphysema	1 (0.8)	0 (0)	1 (1.8)	0 (0)	0.016
Pneumothorax	3 (2.4)	2 (2.9)	1 (1.8)	10 (0.9)	0.104
Pneumopericardium	0 (0)	0 (0)	0 (0)	2 (0,2)	1.000

PA = Port Access; MS = Mini-sternotomy; BV = Bilateral Video Assisted Thoracoscopy; CS = Conventional Sternotomy; CXR = Chest Radiograph; n = Number

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Chapter 7

The relevance of normal chest radiographs in critical care patients

M. Tolsma
K. Willems
N.J.M. van der Meer
P.H.J. van der Voort

ABSTRACT

Introduction. The chest radiograph (CXRs) has firm roots on the intensive care unit (ICU). Evidence on CXR practice has been conflicting during the past decades and different strategies are still in use. CXRs without important findings might also have use for clinical practice. The aim of this study was to address the relation between CXR findings and the number of times a CXR is viewed, in which the last is used as a proxy for clinical relevance.

Methods. We prospectively included all consecutive patients that were admitted to our 20 bed mixed ICU from August 2014 to October 2014. All CXRs that were performed for these patients during their ICU stay were included into the analysis. CXRs were divided into three groups; CXRs without findings, CXRs with minor findings only and CXRs with major findings. The primary endpoint was the number of times a CXR was accessed and this was compared for the three groups.

Results. A total of 1609 CXRs were performed in 339 patients. No findings were present in 18% of CXRs, while 52% of CXRs showed only minor findings and major findings were present in 30% of CXRs. CXRs without any finding were accessed a median number of 4 times per day, while CXRs with minor findings only and CXRs with major findings were viewed a median number of 5 and 6 times per day respectively ($p<0.001$).

Conclusions. The presence of findings on a CXR has a significant effect on the number of times a CXR is accessed. However, CXRs without (major) findings are still viewed relatively often, which supports their usefulness in the clinical process.

INTRODUCTION

The chest radiograph (CXRs) has firm roots in the intensive care unit (ICU) and evidence on ICU CXR practice has been conflicting during the past decades. Traditionally routine CXRs were recommended for all critically ill patients based on the high efficacy and incidence of new findings [1-4]. Later studies however showed a limited diagnostic and therapeutic value of these daily routine CXRs in a mixed ICU population or in mechanically ventilated patients only. [5-10]. Several investigators have also studied the clinical value of routine CXRs following ICU admission or certain procedures like central venous catheterization, endotracheal intubation and chest tube placement or removal [11-19]. They also reported a low diagnostic and/or therapeutic efficacy.

Later studies comparing a routine CXR strategy to an on-demand CXR strategy did not show any difference in primary outcome measures as mortality, ICU length of stay, duration of mechanical ventilation or the use of other imaging studies [20-26]. These studies suggested that a more restrictive CXR strategy would be safe. The meta-analysis by Ganapathy and colleagues [24] however stated that the confidence intervals were wide in these studies and that study populations were small. In addition, the authors stated that possible harm and eventually missed findings were not assessed thoroughly enough. This makes the discussion regarding the optimal CXR strategy and specific indications for CXRs in critically ill patients still ongoing.

Did the outcomes of the several studies change our daily clinical practice? According to the results of our recent web survey of Dutch intensivists it did. A daily routine CXR strategy is a rare practice in the Netherlands nowadays [27]. However, other routine CXR practices have been adopted instead. For example routine CXRs on ICU admission, for certain patient groups, or on certain fixed days a week are still relatively common. So despite the low diagnostic efficacy, intensivists consider that these CXRs still have certain use for patient management. Hypothetically this may concern documentation of disease progress or response to therapy, but also negative findings may be useful in allowing optimal clinical decision-making and doctor and patient logistics [28-29]. The aim of this study was to address a relation between CXR findings and the number of times a CXR is accessed. The relevance of the CXR per se might be found in the number of times it has been viewed and evaluated by the staff over 24 hours. Then we consider the number of views as a proxy for clinical importance. Our hypothesis is that even CXRs without important findings are still viewed an important number of times.

METHODS

This prospective, observational, single centre study was performed in a 20-bed closed format ICU admitting medical, surgical and cardiosurgical patients. The medical staff of this ICU consists of nine intensivists and 7 fellows in ICU medicine. The local medical ethics committee approved the study protocol and the need for informed consent was waived according to Dutch and European legislation, since this study was observational and did not affect patient management at any point. All patient data was collected anonymously.

We prospectively included all consecutive patients that were admitted to our ICU from August to October 2014. All CXRs that were performed for these patients during their ICU stay were included into the analysis. CXRs taken outside the ICU or the study period were excluded. The primary endpoint was the number of times a CXR was viewed and this was used as a simple, objective and straightforward measure for their clinical relevance. Each view was automatically logged in the patient data management system when a CXR was opened and the data of all these views was extracted at the end of the study period.

Demographic data was extracted for all patients using the ICU patient data management system Metavision, IMDsoft, Tel Aviv, Israel. This included age, gender, admitting specialism, admission type, planned/unplanned admission, ICU length of stay (LOS), hospital LOS, ICU mortality, hospital mortality and acute physiology and chronic health evaluation (APACHE IV) score.

All CXRs were assessed both by a radiologist and an ICU physician, while the radiologic report was used as the gold standard. CXR findings were noted and classified according to the overview presented in Table 1 and were divided into minor findings and major findings. All findings were taken into analysis including abnormalities that were already present on a previous CXR.

At performance a CXR was denoted as 'admission routine CXR', 'morning routine CXR' or 'on-demand CXR'. After assessment of the results the CXRs were divided into three groups; CXRs without findings, CXRs with minor findings only and CXRs with major findings. Data on the frequency of CXR accesses was extracted from the ICU server including the date and time the CXR was taken. This was compared for the three groups.

Statistical analysis was performed using IBM SPSS Statistics v21.0 for Windows. Normally distributed variables were denoted using the mean and standard deviation. Ordinal and non-normally distributed variables were denoted using the median and interquartile range. Comparison of a continuous variable between more than two groups

was done using a Kruskal-Wallis test and follow-up by a Mann Whitney U test to compare effect size. Alpha was set on 0.05 for the Kruskal-Wallis test, with a Bonferroni correction to control for type 1 errors, leaving a more stringent alpha level of 0.05/3=0.017 for the Mann Whitney U test.

RESULTS

Table 2 shows the baseline characteristics of the study population. A total of 1609 CXRs were performed in 339 patients. The majority of patients (61%) were male and their mean age was 67 years. The median ICU LOS stay was 1.4 days and ICU mortality was 7.1%. A small majority of patient admissions were planned (57%) and most patients were admitted after thoracic surgery (55%), general surgery (12%) or by internal medicine (15%).

No findings were present in 18% of CXRs, while 52% of CXRs showed only minor findings and major findings were present in 30% of CXRs (Table 3). A total of 2056 minor findings were found on 1140 CXRs. A total of 587 major findings were found on 480 CXRs. Most frequent minor findings were pleural effusion (35%) and atelectasis (36%). Most frequent major findings were consolidation (9.1%) and a widened mediastinum (6.1%) (Table 4).

The percentage of major findings was 27.8% for the 'morning routine' group, 28.1% for the 'admission routine' group and 39.8% for the 'on-demand' group of CXRs ($p<0.001$). The 'on-demand' CXRs were viewed a median of 6 (3-9) times, while the 'admission routine' and 'morning routine' CXRs were viewed a median number of 5 (3-8) and 5 (2-7) times respectively ($p<0.001$).

Table 5 shows the results on the primary outcome. CXRs without any finding were accessed a median number of 4 times, while CXRs with minor findings only and CXRs with major findings were viewed a median number of 5 and 6 times respectively ($p<0.001$).

DISCUSSION

We found a significant relation between the presence of CXR findings and the number of times a CXR is accessed or viewed. In addition, we found that CXRs without findings were still viewed relatively often (median 4 times) which underlines our hypothesis that normal CXRs may also be of clinical importance. As far as we know this is the first study to address these items, and results on the primary endpoint are thus hard to compare

with previous work.

The diagnostic efficacy of CXRs for minor findings (52%) in our study however was comparable to the results of previous studies [10, 30-32]. The diagnostic efficacy of 30% for major findings was notably higher than others reported [8-9, 30-33]. This could be explained by the fact that all findings were taken into account, instead of new findings only which were not seen before on previous CXRs in the same patient. The higher diagnostic efficacy for 'on-demand' CXRs when compared to 'routine' CXRs is also in line with the current evidence [8-10, 30].

Although CXRs without findings or with minor findings only were viewed significantly less times than CXRs with major findings, the effect size was small. These CXRs were still accessed a notable number of times and there was no great difference in this number when compared to CXRs with major findings. This may still support their usefulness in the clinical process.

A limitation of this study may be the assessment of CXR findings by different radiologists. The description of findings may be different between them. On the other hand, our classification of findings was objectified as much as possible using predefined criteria and this classification was used widely before [9, 26, 30-31].

Another possible limitation was the choice of the primary endpoint. The number of times a CXR was viewed was used as a proxy for clinical relevance and importance for the clinical process. As this is the first study that focused on this topic there was no widely used measure before. Not only the number of findings may be a proxy for clinical relevance, but the number of views may be also. It is a simple, straightforward and objective measurement and it may also account for the impact of negative findings as the absence of important pathology may be of influence for clinical and logistic decision-making.

CONCLUSION

The presence of findings on a CXR has a significant effect on the number of times a CXR is accessed. However, CXRs without (major) findings are still viewed relatively often, which supports their usefulness in the clinical process.

Table 1. Classification of radiologic findings.

Minor findings	Major findings
Little pleural effusion [1]	Severe pleural effusion [2]
Small atelectasis [1]	Large atelectasis [2]
Little pulmonary congestion [1]	Severe pulmonary congestion [2]
Small consolidation [1]	Large consolidation [2]
Enlarged heart	Malposition of invasive devices
Pulmonary emphysema	Widened mediastinum
Pulmonary fibrosis	Large subcutaneous emphysema
Costal fracture	Haemothorax
	Pneumothorax
	Pneumomediastinum
	Pneumopericardium
	Free air under diaphragm

[1] Involvement of less than 1 lobe and/or judged 'little, small or minimal' by the radiologist.
[2] Involvement of 1 lobe or more and/or judged 'large, severe or extensive' by the radiologist.

Table 2. Baseline characteristics of the study population.

Patients, n (%)	339 (100)
Gender, male, n (%)	203 (61)
Age, years, median (IQR)	68 (57-75)
APACHE IV, predicted mortality, % (IQR)	4,5 (1.4-27.7)
ICU LOS, days, median (IQR)	1,4 (0.9-3.5)
Hospital LOS, days, median (IQR)	9 (6-17)
ICU mortality, n (%)	24 (7.1)
Hospital mortality, n (%)	34 (10)
Planned admission, n (%)	192 (57)
Type of admission;	
Medical, n (%)	130 (38)
Scheduled surgery, n (%)	174 (54)
Urgent surgery, n (%)	25 (7)
Admitting specialism;	
Thoracic surgery, n (%)	186 (55)
Internal medicine, n (%)	52 (15)
General surgery, n (%)	42 (12)
Cardiology, n (%)	24 (7.1)
Pulmonology, n (%)	14 (4.1)
Neurology, n (%)	8 (2.4)
Other, n (%)	13 (3.8)

n = Number; IQR = Interquartile range; APACHE = Acute physiology and chronic health evaluation; ICU = Intensive Care Unit; LOS = Length of stay

Table 3. Number of chest radiographs with subsequent findings; n = 1609, n (%)

No findings	290 (18)
Any finding	1319 (82)
Minor findings only	839 (52)
Major findings	480 (30)

n = Number

Table 4. Frequencies of specific findings; n=1609, n (%)

Minor findings		Major findings	
Little pleural effusion	559 (35)	Severe pleural effusion	71 (4.4)
Small atelectasis	572 (36)	Large atelectasis	21 (1.3)
Little pulmonary congestion	313 (19)	Severe pulmonary congestion	78 (4.8)
Small consolidation	224 (14)	Large consolidation	147 (9.1)
Enlarged heart	287 (18)	Malposition of invasive devices	67 (4.2)
Pulmonary emphysema	34 (2.1)	Widened mediastinum	98 (6.1)
Pulmonary fibrosis	43 (2.7)	Large subcutaneous emphysema	48 (3.0)
Costal fracture	24 (1.5)	Haemothorax	6 (0.4)
		Pneumothorax	48 (3.0)
		Pneumomediastinum	1 (0.1)
		Free air under diaphragm	2 (0.1)
Total	2056	Total	587
CXRs with any minor finding	1140 (71)	CXRs with any major finding	480 (30)

n = Number; CXR = Chest Radiograph.

Table 5. Number of times chest radiographs were accessed; median (IQR).

CXRs with no findings (n=290)	CXRs with minor findings only (n=839	CXRs with major findings (n=480)	p-value
4 (2-6)	5 (2-7)	6 (4-10)	<0.001

IQR = Interquartile Range; n = Number

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Chapter 8

Morning chest radiographs in the intensive care unit: efficacy versus value

M. Tolsma
M. van Dongen
T.A. Rijpstra
R.A.L. de Waal
L.D. Vos
M. Heijdeman
P.G.H. Mulder
N.J.M. van der Meer

ABSTRACT

Introduction. Routine chest radiographs (CXRs) are still performed frequently in the intensive care unit (ICU) although their diagnostic and therapeutic efficacy is known to be low. A possible for this might be the perceived importance for intensivists to support certain clinical decisions. Our aim was to study this perceived importance of morning CXRs performed routinely in a mixed intensive care unit population and to compare their efficacy between different indication categories and patient groups.

Methods. We prospectively included all CXRs performed during the routine morning round from January to June 2014. Before the morning round we asked the intensivist on call to select an indication for each CXR from a predefined categories list (e.e. 'no specific indication', 'follow-up of a known problem', 'rule out complications before ICU discharge' or 'a new clinical problem'). CXR findings were divided in minor and major findings and the diagnostic efficacy was compared between different patient groups and between the different indication categories. Assuming that CXRs in the indication categories 'no specific indication' and 'rule out complications before ICU discharge' were not performed in an on-demand only CXR strategy, new major findings in these groups were denoted as possible missed findings.

Results. 1740 CXRs were performed for 1347 patients. Most CXRs were taken for the 'follow-up of a known problem' (36%) or to 'rule out complications before ICU discharge' (40%). Minor findings were present in 49% of CXRs and new major findings in 4.0% of CXRs. The diagnostic efficacy for new major findings was low (2.9% to 4.4%) in all patient groups and for all indication categories. Of the patients in the indication category 'rule out complications before ICU discharge' (n=692), 86% could be transferred to the ward on the same day. In this group, 19 out of 26 patients (73%) with new major findings were discharged the same day.

Conclusions. The diagnostic efficacy for new major findings is low for all ICU morning CXRs, regardless of the indication category or patient type. However, a substantial number of CXRs is performed for follow-up or to support an ICU discharge decision. Their importance for medical documentation, clinical management and ICU discharge policy may therefore not be overlooked. This should be judged in every individual case before ordering.

INTRODUCTION

Chest radiographs (CXRs) are performed frequently in the intensive care unit (ICU). On a daily routine basis, routinely at ICU admission, routinely after surgery and other certain procedures, and 'on-demand' because of certain clinical problems. The literature has been conflicting regarding the optimal CXR practice for ICU patients. Early studies recommended routine CXRs for all critically ill patients, because of the high incidence of new findings [1-4]. Later studies however showed a limited value of routine CXRs in a mixed ICU population or in mechanically ventilated patients only [5-10]. This was especially due to the lower incidence of important 'major' findings and the limited number of therapeutic consequences. Investigators that studied the value of routine CXRs on ICU admission or after procedures like endotracheal intubation, central venous catheterization, and chest tube placement or removal, also reported a low efficacy [11-19].

Trials that compared a routine CXR strategy to a so called 'on-demand' CXR strategy were not able to show any difference in important outcome measures like mortality, duration of mechanical ventilation, ICU length of stay or the number of other imaging studies used [20-26]. These reports suggested that an 'on-demand only' strategy would be safe. However, afterwards an important meta-analysis stated, that the study populations were small, confidence intervals were wide and that possible harm and potential 'missed findings' were not assessed good enough [24]. Now, the discussion regarding the optimal CXR practice is still ongoing today.

In our web survey of Dutch intensivists in 2013 we showed that a daily routine CXR practice is only performed in a very small number of ICUs in the Netherlands nowadays [27]. Instead, other routine strategies like routine CXRs for certain patient groups only, routine CXRs on certain fixed days a week, or routine CXRs on the first days of admission only, are now more common. We also showed that intensivists still consider these CXRs to be valuable for patient management for other reasons than the studied diagnostic efficacy for new major findings. Hypothetically, a reason for this may be the documentation of disease progress or response to therapy, but it may also support the perceived safety of an ICU discharge decision. In such cases, even small or negative findings may be of value in allowing optimal clinical decision-making and optimizing patient logistics [28-29]. The aim of this study was to study the professional reasons for obtaining morning CXRs in a mixed intensive care unit population. We compared the diagnostic efficacy of these CXRs between different indication categories and patient groups and attempted to measure other values. We also investigated what important findings could have been missed in an 'on-demand only' strategy and depicted the correlation with the ICU length of stay after these findings.

METHODS

This observational, prospective study was performed in a 24-bed closed format ICU admitting surgical, medical and cardiosurgical patients. A daily routine morning CXR strategy was common practice on this ICU. The local medical staff consisted of sixteen intensivists and eight residents in ICU medicine. The local ethics committee (AMOA, Amphia Hospital, Breda, The Netherlands) approved the study protocol and waived the need for informed consent, since this study was purely observational and did not affect the regular patient management.

We prospectively included all CXRs performed in the routine morning round in our ICU from January to June 2014. Accordingly, for a single patient multiple CXRs could be included. CXRs taken outside the morning round were not included. During the nightshift, and close before the CXR morning round, we asked the intensivist on call to select an indication for this CXR from a predefined indication categories list; 'no specific indication', 'follow-up of a known problem', 'rule out complications before ICU discharge' or 'a new clinical problem'. This was made possible by an automatic pop-up form in the patient data management system. It was also noted whether the patient was on mechanical ventilation or not, and the physician was asked whether ICU discharge was a possibility during the upcoming day.

Demographic data was collected for all patients using the local patient data management system, Metavision, IMDsoft, Tel Aviv, Israel. This included gender, age, admission type, admitting specialism, ICU length of stay (LOS) and the acute physiology and chronic health evaluation (APACHE IV) score.

All morning CXRs were assessed both by a radiologist and by a single intensivist. All CXR findings were denoted according to the classification presented in Table 1. They were divided into minor and major findings. For major findings it was also denoted whether this was finding was already present on the previous CXR for this patient or not. The diagnostic efficacy was calculated for all CXRs and was compared between different patient groups (medical, surgical, cardiac surgical) and between the different indication categories. Assuming that CXRs in the categories 'no specific indication' and ' rule out complications before ICU discharge' were probably not performed in an 'on-demand only' CXR strategy, the new major findings in these CXR categories were shown apart as the so called possible 'missed findings'. The correlation with the ICU LOS after these findings was also depicted.

Statistical analysis was performed using IBM SPSS Statistics v21.0 for Windows. The distributions of categorical variables are presented as absolute and relative frequencies (percentages). The distributions of continuous variables are presented as means and standard deviations. Findings were categorized into no and any, any findings were further sub-categorized into minor and major findings, major findings into old and new major findings and new major findings into types of new major findings. By means of cross tables each of those categorizations or sub-categorizations was compared between patient and indication categories and tested by using the chi-squared or Fisher's exact test when appropriate.

RESULTS

In Table 2 the baseline characteristics of the morning CXRs and the study population are shown. 1740 CXRs were performed in 1347 patients. The majority of CXRs was performed in male patients (63%) and 60% of all CXRs were performed in mechanically ventilated patients. The patients mean age was 67±13 years and their mean APACHE IV score was 65±29. A small majority of all CXRs was taken in cardiac surgical patients (53%), while 31% was taken in medical patients and 16% in surgical patients. According to the predefined indication categories, most CXRs were taken for follow-up of a known problem (36%) or to rule out complications before ICU discharge (40%). In 22% of CXRs the physicians stated to have no clear indication and in only 2% of cases the CXR was performed because of a new clinical problem.

No findings were present in 38% of all cases, while 49% of CXRs showed only minor findings (Table 3). Major findings were found in 13% of CXRs and 'new' major findings were present in 4% of the CXRs. The most frequently found minor findings were atelectasis (23%) and pleural effusion (19%). A large consolidation and severe pulmonary congestion were the most frequent major findings (4.7% and 2.9% respectively), while a pneumothorax was the most frequent new major finding (1.0%).

Major findings were more frequently found in medical patients (22%) compared to surgical and cardiac surgical patients (13% and 7.4%)($p<0.0005$)(Table 4). Surgical patients showed less new major findings (2.9%) when compared to medical patients (4.2%) and cardiac surgical patients (4.2%)($p<0.0005$).

In Table 5 the diagnostic efficacy is compared for the different indication categories. Major findings were the most frequent seen in the category 'follow-up of a known problem' (22%), and were seen less in the other categories (8.9%, 5.8% and 5.9%)($p<0.0005$). The difference in new major findings was again significant but very small between the four groups (2.9% for the 'new clinical problem' group compared to 3.8%, 4.0% and 4.4% in the other groups)($p<0.005$). There was no significant difference in the type of new

major findings between the groups, except for that a large consolidation was seen relatively frequent in the 'new clinical problem' group (p=0.016)(Table 6).

Following new major CXR findings in the 'no specific indication' group, all patients with intended ICU discharge could still leave the ICU on the same day. None of the cardiac surgical patients in this group had to stay longer on the ICU. The 'rule out complications before ICU discharge' group consisted for 88% of cardiac sugical patients. Of all patients in this group 86% (n=599 out of n=692) could indeed be discharged from the ICU on the same day. Nineteen of the 26 patients (73%) with new major findings in this group could be discharged from the ICU on the same day, leaving only 7 patients to stay on the ICU.

DISCUSSION

In accordance to earlier studies, we found that the overall diagnostic efficacy of routinely performed morning CXRs in a mixed ICU population is high for minor findings but low for new major findings. In addition, we found a significant but only small difference in the presence of new major findings between different patient groups and different indication categories. The number of findings that could have been missed in an on-demand only strategy was minimal and these findings had little impact on ICU LOS.

The diagnostic efficacy we found for minor findings (49%) was in line with the results of previous studies [10, 30-32]. The diagnostic efficacy of 4.0% for new major findings is also comparable to results that others reported [8-9, 30-33]. By our knowledge this was the first study to compare the results of morning CXRs between different indication categories. We either did not find other studies that evaluated possible missed findings in combination with ICU LOS.

We found that CXRs performed for medical patients show more major findings. However, the difference in the presence of new major findings between the different patient groups was only small, and this number was low for all groups (3-4%). It may not be surprising that CXRs in the indication group 'follow-up of a known problem' did show more major findings. The difference in the presence of new major findings was again only small between the different indication categories and numbers were comparable low here (3-4%). The indication 'follow up of a known problem' was chosen in 36% of cases and although their diagnostic efficacy for new findings is low, the importance of these CXRs for medical documentation and clinical decision-making is hard to study.

We assumed that the CXRs in the categories 'no specific indication' and 'rule out complications before ICU discharge' were not performed in an on-demand only CXR strategy, and CXR findings in these categories could then have been missed. The number of new major findings in these groups was as mentioned only minimal (4.4% and 3.8% respectively). We also showed that these findings had little impact on ICU LOS as large majority of these patients could still be discharged from ICU on the same day. The indication 'rule out complications before ICU discharge' was however chosen in 40% of all CXRs, implicating that a CXR is of value in supporting a professionals decision for ICU discharge. Of these patients, 86% could indeed be transferred to the ward on the same day. The presence or especially the absence of CXR findings could have been of certain importance in this clinical and logistic decision.

The first limitation of this study is that it was a purely observational and single center study, without randomization. CXRs were performed anyway according to the local routine morning CXR strategy. This study design, however, did make us able to compare the efficacy of different indication categories for morning CXRs and to evaluate for possible missed findings in an on-demand CXR strategy. A second study limitation is that different ICU physicians chose the indication for the upcoming CXR. This judgement may be different between them, but in reality different physicians ranging from minimally experienced to very experienced order CXRs.

Now we showed that the diagnostic efficacy of morning CXRs is low for all indication categories and patient groups, we advise that their importance for clinical management, documentation and discharge policy should be judged in every individual case. An experienced ICU physician should ideally do this.

CONCLUSION

The diagnostic efficacy for new major findings is low for all ICU morning CXRs, regardless of the indication category or patient type. However, a substantial number of CXRs is performed for follow-up or to support an ICU discharge decision. Their importance for medical documentation, clinical management and ICU discharge policy may therefore not be overlooked. This should be judged in every individual case before ordering.

Table 1. Classification of radiologic findings.

Minor findings [1]	Major findings [2]
Minimal pleural effusion	Severe pleural effusion
Small atelectasis	Large atelectasis
Minimal pulmonary congestion	Severe pulmonary congestion
Small consolidation	Large consolidation
	Malposition of invasive devices
	Widened mediastinum
	Large subcutaneous emphysema
	Haemothorax
	Pneumothorax
	Pneumomediastinum
	Pneumopericardium
	Free air under diaphragm

[1] Involvement of less than one lobe, and/or judged 'normal postoperative'
[2] Involvement of one lobe or more, and/or judged 'no normal postoperative finding'

Table 2. Baseline data of the study population and the morning CXRs performed.

CXRs, n	1740
CXRs for male patients, n (%)	1101 (63)
Patient age, years, mean ± SD	67 ± 13
Patient APACHE IV score, mean ± SD	65 ± 29
CXRs for ventilated patients, n (%)	1050 (60)
CXRs before possible ICU discharge, n (%)	1100 (63)
CXRs for patient category, n (%)	
Cardiosurgical	915 (53)
Medical	546 (31)
Surgical	279 (16)
CXRs for specified indication category, n (%)	
No specific indication	383 (22)
Follow-up of know problem	631 (36)
Rule out complications before ICU discharge	692 (40)
A new clinical problem	34 (2.0)
Poor oxygenation	8
High infection parameters	6
A recent procedure	5
Fever	2
Suspicion of bleeding	3
Suspicion of cardiac tamponade	2
Suspicion of pneumothorax	1
Poor pulmonary compliance	1
Missing	6

CXR = Chest Radiograph; n = Number; SD = Standard Deviation; APACHE = Acute Physiology and Chronic Health Evaluation; ICU = Intensive Care Unit

Table 3. The number and type of CXR findings. (n=1740)

CXRs with no findings, n (%)	656 (38)	
CXRs with any finding, n (%)	1084 (62)	
CXRs with minor findings only, n (%)	860 (49)	
CXRs with major findings, n (%)	224 (13)	
CXRs with new major findings, n (%)	69 (4.0)	
	Found	New
Minor findings;		
Minimal pleural effusion, n (%)	329 (19)	n.a.
Small atelectasis, n (%)	406 (23)	n.a.
Minimal pulmonary congestion, n (%)	232 (13)	n.a.
Small consolidation, n (%)	247 (14)	n.a.
Major findings;		
Severe pleural effusion, n (%)	29 (1.7)	7 (0.4)
Large atelectasis, n (%)	4 (0.2)	0 (0)
Severe pulmonary congestion, n (%)	50 (2.9)	12 (0.7)
Large consolidation, n (%)	81 (4.7)	8 (0.5)
Malposition of invasive devices, n (%)	6 (0.3)	5 (0.3)
Widened mediastinum, n (%)	24 (1.4)	15 (0.9)
Large subcutaneous emphysema, n (%)	9 (0.5)	7 (0.4)
Pneumothorax, n (%)	30 (1.7)	18 (1.0)
Pneumomediastinum, n (%)	3 (0.2)	2 (0.1)
Other, n (%)	1 (0.1)	0 (0)

CXR = Chest Radiograph; n = Number; n.a. = Not applicable

Table 4. Number of morning CXRs with minor and major findings per patient category. (n=1740)

	Cardiosurgical n=915	Medical n=546	Surgical n=279	p-value
CXRs with no findings, n (%)	396 (43)	167 (31)	93 (33)	p < 0.0005
CXRs with any finding, n (%)	519 (57)	379 (69)	186 (67)	
CXRs with minor findings only, n (%)	451 (49)	258 (47)	151 (54)	p < 0.0005
CXRs with major findings, n (%)	68 (7.4)	121 (22)	35 (13)	
CXRs with old major findings, n (%)	30 (3.3)	98 (18)	27 (9.7)	p < 0.0005
CXRs with new major findings, n (%)	38 (4.2)	23 (4.2)	8 (2.9)	

CXR = Chest Radiograph; n = Number

Table 5. Number of morning CXRs with minor and major findings per stated indication category. (n=1740)

	NSI n=383	FUKP n=631	RCBD n=692	NCP n=34	p-value
CXRs with no findings, n (%)	155 (40)	162 (26)	327 (47)	12 (35)	p = 0.001
CXRs with any finding, n (%)	228 (60)	469 (74)	365 (53)	22 (65)	
CXRs with minor findings only, n (%)	194 (51)	321 (51)	325 (47)	20 (59)	p < 0.0005
CXRs with major findings, n (%)	34 (8.9)	148 (23)	40 (5.8)	2 (5.9)	
CXRs with old major findings, n (%)	17 (4.4)	123 (19)	14 (2.0)	1 (2.9)	p < 0.0005
CXRs with new major findings, n (%)	17 (4.4)	25 (4.0)	26 (3.8)	1 (2.9)	

CXR = Chest Radiograph; NSI = No specific indication; FUKP = Follow-up of known problem; RCBD = Rule out complications before ICU discharge; NCP = New clinical problem; n = Number

Table 6. Specification of new major findings per stated indication category. (n=1740) (one CXR may have more than one type of major finding)

	NSI	FUKP	RCBD	NCP	
	n=383	n=631	n=692	n=34	p-value
Severe pleural effusion, n (%)	2 (0.5)	3 (0.5)	2 (0.3)	-	p = 0.82
Severe pulmonary congestion, n (%)	3 (0.8)	7 (1.2)	2 (0.3)	-	p = 0.30
Large consolidation, n (%)	-	6 (1.0)	1 (0.1)	1 (2.9)	p = 0.016
Malposition of invasive devices, n (%)	-	3 (0.5)	2 (0.3)	-	p = 0.44
Widened mediastinum, n (%)	7 (1.8)	1 (0.2)	7 (1.0)	-	p = 0.031
Large subcutaneous emphysema, n (%)	2 (0.5)	2 (0.3)	3 (0.4)	-	p = 0.91
Pneumothorax, n (%)	4 (1.0)	3 (0.5)	10 (1.4)	-	p = 0.32
Pneumomediastinum, n (%)	1 (0.3)	-	1 (0.1)	-	p = 0.71

CXR = Chest Radiograph; NSI = No specific indication; FUKP = Follow-up of known problem; RCBD = Rule out complications before ICU discharge; NCP = New clinical problem; n = Number

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Chapter 9

Summary and recommendations

M. Tolsma

SUMMARY

The diagnostic efficacy of chest radiographs (CXRs) for critically ill patients is known to be low, and previous studies did not show any difference in important clinical outcome measures between a routine CXR strategy and an on-demand only CXR strategy. However, this evidence seems hard to implicate into the clinical practice, since the number of (routine) CXRs ordered for critically ill patients is still high. In this thesis we studied the CXR ordering practice of Dutch intensivists in order to give recommendations for the optimization of this process and to reduce workload, costs, and radiation to the patients. Aside from the diagnostic efficacy of intensive care unit (ICU) CXRs, we attempted to identify reasons for their clinical importance, even when no important (new) findings are present. We also attempted to identify certain patient groups that may still benefit from the performance of routine CXRs. According to the routine CXR strategies on our study ICUs, and the observational study designs, we were able to evaluate for potential missed findings in an on-demand only CXR strategy.

In **Chapter 2** we presented a new web-survey of Dutch intensivists regarding their CXR ordering practice. The results were compared to the results of a similar survey performed in 2005. We found that a daily routine CXR strategy is a rare practice nowadays in our country (only 7% of ICUs). However, certain other routine strategies, like routine CXRs on the first days of admission, on certain days a week, or for mechanically ventilated patients or cardiosurgical patients only, are still common (39% of ICUs). We also found that intensivists still assume the value of their CXRs performed to be higher than the diagnostic efficacy that is reported in the literature.

After this survey we sent a letter to the editor of *Critical Care* on this topic that is presented in **Chapter 3**. It seems obvious that the discussion regarding the optimal CXR strategy for ICU patients is still ongoing today, despite that the diagnostic efficacy of ICU CXRs is known to be low, and despite that several investigators found no harm associated with a more restrictive on-demand CXR strategy in their studies. An interesting point of view may be the impact of a CXR strategy on the local workflow, where a number of issues are not studied before. We hypothesized that the importance of (negative) CXR findings for medical documentation, clinical management, and decision-making as discharge policy may be larger than is estimated.

Since performing routine CXRs for postoperative cardiac surgery patients is a common practice around the world, we decided to study the diagnostic value of CXRs for this patient group, which we presented in **Chapter 4**. We found that the overall diagnostic efficacy of 33.5% for all findings in these patients, but in agreement with

previous studies in a general ICU population, the therapeutic efficacy was low (2.4%). We found a poor correlation between clinical assessment by an ICU physician and important CXR findings implicating that this may not be an appropriate alternative for performing a CXR. The number of CXR findings after drain removal was only minimal (6%) and none of these patients needed a subsequent intervention.

Following the elimination of routine CXRs after chest tube removal on our ICU, we did a new study in which direct postoperative CXRs after cardiac surgery were now also performed for certain predefined indications only. The results are presented in **Chapter 5**. In this strategy the total number of direct postoperative CXRs was reduced by 73% and the CXRs performed on indication showed to have a significantly higher efficacy for major abnormalities. Of all patients that did not meet the criteria for a direct postoperative CXR, only 0.6% had the need for a subsequent intervention after a control CXR performed on the next morning. None of these patients experienced an adverse event.

For the cardiac surgery population we placed special attention on minimally invasive cardiac surgery patients (mostly valve surgery and rhythm surgery patients) to investigate whether important CXR findings are more common after these new surgical techniques. In **Chapter 6** we compared the CXR results after these procedures to the CXR results after conventional cardiac surgery. Major findings were significantly more frequent present after surgery by port access or bilateral video assisted thoracoscopy (VATS), when compared to patients who had surgical access by mini-sternotomy or full median sternotomy (8.9% and 11% versus 4.3% and 3.8%). The number of subsequent interventions was also higher in the first patient groups although this difference was only close to being significant.

For a mixed ICU population, we attempted to address the relevance of negative CXR findings in **Chapter 7**. For all CXRs performed in this population, we measured the number of times that a CXR was viewed, in which this number was used as a proxy for clinical relevance. Although we did find a significant relation between the presence of CXR findings and the number of CXR views, this difference was small and CXRs without important findings were still accessed relatively often. This finding might support a certain role for CXRs in clinical practice aside from their diagnostic efficacy for new major findings alone.

In **Chapter 8** we present the results of a study on the performance of morning round CXRs in a mixed ICU population. In an attempt to identify indications for morning CXRs that are professionally perceived as important for intensivists, we asked them to state an indication for every morning CXR performed. We subsequently compared

the diagnostic value between different indication categories and patient groups. We found a low diagnostic efficacy for new major findings for all morning CXRs, independent from the chosen indication or the type of patient. However, since most CXRs were performed for 'follow-up of a known problem' (36%) or to 'rule out complications before ICU discharge' (40%), these CXRs might have a certain role in medical documentation, clinical management or patient logistics that should not be overlooked but specifically addressed in order to successfully introduce a new CXR protocol.

RECOMMENDATIONS

We do not recommend the performance of a physical assessment as a single alternative for obtaining a CXR in postoperative cardiac surgery patients, since the correlation with CXR findings was poor in our study. Routine CXRs after chest tube removal have a minimal diagnostic efficacy in this patient group and had no impact on clinical management in our study population. We recommend ICUs to consider elimination of these CXRs from clinical practice. Furthermore, we recommend all ICUs that admit cardiac surgery patients to state clear indications for a direct postoperative CXR at ICU admission, as this number of CXRs may be safely reduced in this condition. It seems reasonable to perform at least one (routine) CXR in the first 24 hours after cardiac surgery. Routine CXRs after minimally invasive cardiac surgery should still be considered because of their higher efficacy for major findings.

In line with the available evidence, the diagnostic efficacy of CXRs for new major findings was low in our mixed ICU population (3-4%) and similarly low for our postoperative conventional cardiac surgery patients. However, the importance of (positive and negative) CXR results for clinical management, documentation and patient logistics is hard to study and may be larger than is estimated. This may also be different for individual ICU departments, intensivists and patients. We therefore recommend all ICUs to design a clear local protocol regarding their CXR indications. Ideally, an experienced ICU physician should judge the importance of performing a CXR in every individual condition before ordering.

NEDERLANDSE SAMENVATTING

De diagnostische effectiviteit van thoraxfoto's (een röntgenfoto van borstkas, hart en longen, in het Engels 'chest X-rays', afgekort 'CXRs') voor patiënten op de intensive care (IC) is laag. Eerdere studies lieten geen verschil zien in belangrijke uitkomsten tussen het uitvoeren van een routine CXR strategie of een strategie waarbij CXRs alleen op specifieke indicatie worden verricht. Dit bewijs lijkt echter moeilijk te impliceren in de klinische praktijk, aangezien er nog steeds op grote schaal (routine) CXRs worden aangevraagd voor IC patiënten. In dit proefschrift onderzochten we het CXR aanvraag gedrag van Nederlandse intensivisten (intensive care specialisten) om tot aanbevelingen te komen voor het optimaliseren van dit proces. Dit om kosten, werkbelasting voor personeel en straling voor de patiënt te reduceren. Naast de diagnostische waarde van CXRs voor IC patiënten, hebben we getracht om andere redenen voor de klinische relevantie van deze foto's te identificeren, ook als er geen belangrijke bevindingen zijn. We hebben tevens getracht om patiëntengroepen te identificeren die wel gebaat kunnen zijn bij het verrichten van routine CXRs. Dankzij de routine CXR strategie op de IC afdelingen waar de onderzoeken plaatsvonden en onze observationele studie ontwerpen, waren we in staat om te evalueren welke bevindingen gemist hadden kunnen zijn in een strategie waarin CXRs alleen op indicatie zouden zijn verricht.

In **Hoofdstuk 2** presenteren we een web-studie naar het CXR aanvraag gedrag van Nederlandse intensivisten. De resultaten werden vergeleken met eenzelfde studie welke verricht werd in 2005. We constateerden dat een dagelijkse routine CXR strategie tegenwoordig zeldzaam is in ons land (slechts 7% van de IC afdelingen). Andere routine CXR strategieën, zoals bijvoorbeeld een CXR op de eerste paar dagen van IC opname, een CXR op vaste dagen in de week, of routine CXRs voor alle beademde- of alle hartchirurgische patiënten, zijn echter nog steeds relatief gewoon (39% van de IC afdelingen). Een opvallende bevinding was dat intensivisten de waarde of effectiviteit van CXRs nog steeds hoger inschatten dan de diagnostische waarde die in de literatuur wordt gerapporteerd.

Na deze web-studie schreven we een brief aan de hoofdredacteur van het tijdschrift 'Critical Care', welke is te vinden in **Hoofdstuk 3**. Ondanks de lage diagnostische waarde van IC CXRs in de literatuur, en ondanks dat diverse onderzoekers geen belangrijke nadelen vonden van een restrictieve CXR strategie, lijkt de discussie over de meest optimale CXR strategie nog steeds gaande. Een belangrijk ander gezichtspunt is de mate waarin de CXR strategie het lokale werkproces beïnvloedt. Dit is nog nooit onderzocht. Onze hypothese is dat ook wanneer er geen belangrijke bevindingen zijn

op de CXRs, dit toch van belang kan zijn voor zaken als medische documentatie, het klinisch handelen en logistieke beslissingen als wanneer een patiënt van de IC kan worden ontslagen.

Het maken van routine CXRs voor patiënten na hartchirurgie is een gewoonte over de gehele wereld. We besloten om de diagnostische waarde van routine CXRs voor deze specifieke patiëntengroep te onderzoeken. De resultaten presenteren we in **Hoofdstuk 4**. We vonden een diagnostische effectiviteit van 33.5% voor de gehele studiegroep. De therapeutische effectiviteit (wanneer een bevinding leidt tot een verandering in het beleid) was echter beperkt tot 2.4%. We vonden een beperkte correlatie tussen de bevindingen bij lichamelijk onderzoek en belangrijke bevindingen op de CXRs. Dit impliceert dat het doen van lichamelijk onderzoek, in deze setting, geen goed alternatief is voor het maken van een CXR. Het aantal bevindingen op CXRs die werden gemaakt na het verwijderen van thoraxdrains was slechts minimaal (6%). Geen van deze patiënten had vervolgens een interventie nodig.

Na het elimineren van routine CXRs na het verwijderen van thoraxdrains, deden we een vervolgstudie waarin voor patiënten direct na een hartoperatie, alleen een CXR werd verricht op bepaalde vooraf gedefinieerde indicaties. De resultaten zijn gepresenteerd in **Hoofdstuk 5**. In deze nieuwe strategie werd het aantal direct postoperatieve CXRs gereduceerd met 73%, terwijl de diagnostische effectiviteit van de CXRs die wel gemaakt werden nu duidelijk hoger was. Voor alle patiënten die geen indicatie hadden voor een direct postoperatieve CXR werd een controle CXR verricht op de volgende morgen. In slechts 0.6% van deze gevallen was er nog een interventie nodig en bij geen van deze patiënten trad een belangrijke complicatie op.

Binnen de populatie van hartchirurgische patiënten besteedden we speciale aandacht aan de groep die een minimaal invasieve hartoperatie onderging (vaak een kleoperatie of een hartritme operatie), om te onderzoeken of belangrijke CXR bevindingen vaker voorkomen na deze relatief nieuwe operatie technieken. In **Hoofdstuk 6** vergeleken we de CXR resultaten na deze operaties met de CXR resultaten na conventionele hartoperaties. Belangrijke bevindingen waren significant vaker aanwezig bij patiënten na een minimaal invasieve operatie vergeleken met patiënten na een traditionele operatie (8.9% en 11% tegenover 4.3% en 3.8%).

Voor een algemeen gemengde IC populatie deden we een poging om de waarde van CXRs zonder belangrijke bevindingen te onderzoeken in **Hoofdstuk 7**. Gedurende een periode van enkele maanden werd voor alle CXRs geregistreerd hoe vaak de resultaten werden opgevraagd. Dit aantal werd gebruikt als maat voor de klinische relevantie van deze CXRs. Hoewel er een significante relatie werd gevonden tussen de

aanwezigheid van bevindingen en het aantal keer dat de resultaten werden bekeken, waren deze verschillen klein. Ook CXRs zonder belangrijke bevindingen werden relatief vaak bekeken. Dit ondersteunt de hypothese dat er meer waarde van CXRs is voor de klinische praktijk dan alleen de diagnostische waarde voor grote bevindingen.

In **Hoofdstuk 8** presenteren we de resultaten van een studie naar de waarde van het maken van dagelijkse ochtend routine CXRs voor een gemengde IC populatie. In een poging om de belangrijkste redenen van intensivisten voor het maken van ochtend CXRs te identificeren, werd ze gevraagd om voor elke ochtend CXR een reden te documenteren. De diagnostische effectiviteit werd vergeleken tussen verschillende patiëntengroepen en indicatie categorieën. We vonden een vergelijkbaar lage diagnostische effectiviteit voor belangrijke bevindingen voor alle patiënt- en indicatie groepen. De meeste CXRs werden gemaakt ten behoeve van 'het vervolgen van een bekend probleem' (36%) of 'het uitsluiten van complicaties voor IC ontslag' (40%). Dit impliceert opnieuw dat er naast de diagnostische effectiviteit, ook een rol is van CXRs voor medische documentatie, het maken van klinisch beleid en het nemen van logistieke beslissingen. Deze rol zal meest waarschijnlijk niet onderschat moeten worden.

AANBEVELINGEN

We raden aan om het verrichten van direct postoperatieve CXRs na hartchirurgie niet alleen te vervangen door het uitvoeren van een lichamelijk onderzoek, omdat correlatie tussen de resultaten en de aanwezigheid van belangrijke CXR bevindingen matig was in onze studie. Routine CXRs na het verwijderen van thoraxdrains hebben een minimale diagnostische waarde en hadden geen impact op het klinisch beleid in onze studie populatie. We raden aan om deze routine CXRs uit de klinische praktijk te verwijderen. Vervolgens raden we alle IC afdelingen die postoperatieve hartchirurgische patiënten opnemen aan om duidelijke afspraken te maken over de indicaties voor een direct postoperatieve CXR. Dit aantal kan waarschijnlijk veilig fors verlaagd worden. Het lijkt redelijk om tenminste één (routine) CXR te verrichten in de eerste 24 uur na hartchirurgie. Een routine CXR direct na minimaal invasieve hartchirurgie zal nog steeds overwogen moeten worden omdat er vaker belangrijke afwijkingen worden gevonden.

In overeenstemming met het beschikbare bewijs uit de literatuur, was de diagnostische effectiviteit van CXRs voor nieuwe belangrijke bevindingen laag (3-4%) voor al onze IC patiënten, inclusief de postoperatieve hartchirurgische patiënten. Echter, de waarde (ook als er geen belangrijke bevindingen zijn) voor medische documentatie, klinisch beleid en het nemen van logistieke beslissingen is moeilijk te onderzoeken en

zal waarschijnlijk niet onderschat moeten worden. Deze waarde kan ook verschillen voor diverse IC afdelingen en verschillende intensivisten. Daarom adviseren we aan alle IC afdelingen om duidelijke afspraken te maken over CXR indicaties. In het meest ideale geval zal een ervaren IC dokter het belang van een CXR in elk individueel geval moeten beoordelen.

LIJST VAN PUBLICATIES

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WETENSCHAPPELIJKE VOORDRACHTEN

The Clinical Value of Routine Chest Radiographs in the first 24 Hours after Cardiac Surgery.
NVA Anesthesiologendagen 2010, Maastricht, Nederland.
EACTA 2010, Edinburgh, Schotland.

Fatal neuroleptic malignant-like syndrome in a patient with severe parkinson disease.
NVA Anesthesiologendagen 2012, Maastricht, Nederland.

Significant changes in the practice of chest radiography in dutch intensive care units.
NVIC intensivistendagen 2014, 's-Hertogenbosch, Nederland.
ISICEM 2014, Brussel, Belgie.

Stating clear indications for chest radiographs after cardiac surgery increases their efficacy and reduces their number.
NVIC intensivistendagen 2014, 's-Hertogenbosch, Nederland.
ISICEM 2014, Brussel, Belgie.
EACTA 2014, Florence, Italie.

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CURRICULUM VITAE

Martijn Tolsma werd geboren op 19 februari 1979 in Alphen a/d Rijn. Daar groeide hij op en deed hij VWO aan het Ashram College. In 1997 begon hij aan de studie Nederlands Recht aan de Universiteit Utrecht, waar hij twee jaar later overstapte naar de studie Geneeskunde. In 2005 behaalde hij zijn doctoraal en artsendiploma. Tussen 2005 en 2008 was hij achtereenvolgens werkzaam als arts-assistent heelkunde in het IJsselland Ziekenhuis in Capelle a/d IJssel en als arts-assistent intensive care in het Amphia Ziekenhuis te Breda. Van 2008 tot 2013 werd hij opgeleid tot anesthesioloog in het Sint Antonius Ziekenhuis in Nieuwegein, waar hij ook het aandachtsgebied cardiothoracale- en vasculaire ingrepen deed. Vervolgens was hij van 2013 tot 2014 fellow intensive care in het UMC Utrecht. En sindsdien werkt hij met veel plezier als anesthesioloog en intensivist in de Isala Klinieken in Zwolle. In zijn vrije tijd doet hij graag aan sport, luistert hij muziek, bezoekt hij concerten en speelt hij gitaar. Martijn woont samen met Anne en hun dochters Suzanne en Evi in Utrecht.