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Low Value of Routine Chest Radiographs in a Mixed Medical-Surgical ICU*

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Objective: **To determine the diagnostic efficacy (DE) and therapeutic efficacy (TE) of daily routine chest radiographs (CXRs), and to establish the impact of abandoning this CXR from daily practice on total CXR volume, ICU length of stay (LOS), readmission rate, and ICU mortality.**
Design: **Prospective controlled study in two parts. The first part comprised a 1-year period during which attending physicians were blinded for findings on daily routine CXRs and were only informed if something deemed important was seen by the radiologist (predefined major abnormalities) who reviewed all CXRs as usual. The second part comprised a half-year period during which daily routine CXRs were replaced by clinically indicated CXR.**
Setting: **Mixed medical-surgical ICU of a teaching hospital.**
Results: **Data on 1,780 daily routine CXRs in 559 hospital admissions were collected. DE of daily routine CXRs was 4.4%. The most frequent unexpected major abnormalities were new or progressive infiltrates (1.8%) and oropharyngeal tube malposition (0.7%). TE of daily routine CXRs was 1.9%. The most frequent intervention was oropharyngeal tube adjustment (0.6%). No relation was found for DE or TE and hospital admission type or intubation and mechanical ventilation. In the second study part, 433 CXRs were obtained in 274 admissions. Abandoning daily routine CXRs did not affect clinically indicated CXRs orders, or ICU LOS, readmission rate, and mortality. A total CXR volume reduction of 35% (which equaled $9,900 per bed per year [US dollars]) was observed after abandoning daily routine CXRs.**
Conclusion: **Diagnostic and therapeutic value of the daily routine CXR is low. Daily routine CXRs can be safely abandoned in the ICU.** ***(CHEST 2007; 132:823–828)***

Key words: critical care; daily-routine chest radiograph; ICU

Abbreviations: CXR = chest radiograph; DE = diagnostic efficacy; IQR = interquartile range; LOS = length of stay; PACS = picture archiving and communication system; TE = therapeutic efficacy

In ICUs, chest radiographs (CXRs) are frequently obtained on a daily basis.[1] These so-called "daily routine" CXRs are made irrespective of the patient's clinical status, which is in line with recommendations by the American College of Radiology for ICU patients.[2] However, obtaining daily routine CXRs is a labor-intensive strategy, while diagnostic and therapeutic yields of daily routine CXRs are low.[3–8]

One could therefore argue that CXRs should only be obtained when clinically indicated, which was substantiated by three previous studies.[9–12] However, these studies were either small,[9,10] performed in children,[9] or performed in academic and tertiary referral ICUs with a relatively high number of physicians and nurses per bed.[9] This setting makes the results difficult to generalize to a general ICU population. In addition, the attending physicians were not blinded for findings on daily routine CXRs. Thus, no information was obtained about the presence of pathology on the routine CXR that was clinically unsuspected. In order to judge whether abolishing a daily routine CXR strategy is indeed warranted, knowledge of the presence of clinically significant pathology that otherwise would have gone undetected is essential.

We evaluated the diagnostic and therapeutic effi-

cacy of daily routine and clinically indicated CXRs in a prospective controlled blinded study in a nonacademic, mixed medical-surgical ICU. In addition, effects of abandoning the daily routine CXRs strategy on CXR volume, ICU length of stay (LOS), readmission rate, and mortality were evaluated during a 6-month implementation phase.

Materials and Methods

We performed a prospective observational study evaluating the diagnostic and therapeutic value of all CXRs of patients admitted to the ICU during a period of 1 year. During this study period, we compared daily routine and clinically indicated CXRs in the same patient group. Thereafter, the daily routine regimen was abolished, all CXRs required a clinical indication, and data were collected for an additional half-year period (implementation phase).

The study was approved by the local ethical board. The requirement to obtain informed consent was waived because this study evaluated a routine approach, and all daily routine CXRs were evaluated by trained radiologists.

Study Location

The study was performed in the ICU of the Gelre Hospitals, Lukas site, a 985-bed university-affiliated teaching hospital in Apeldoorn, the Netherlands. The ICU is a 10-bed "closed format" department with medical and surgical patients. Cardiothoracic surgery and neurosurgery are not performed in our hospital. The ICU team comprises two full-time ICU physicians, five physicians who participate in evening and night shifts, and one resident.

CXR Protocol, Study Phase

A daily routine CXR was obtained every day in all patients at 8:00 AM during the 1-year study phase. These daily routine CXRs were not accessible in the picture archiving and communication system (PACS) to attending physicians responsible for daily clinical care during the ICU stay, and could only be retrieved when radiologists involved in scoring of daily routine CXRs logged-on to the PACS.

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In addition to the daily routine CXR, the attending physicians ordered additional CXRs if deemed clinically necessary. These clinically indicated CXRs were, in contrast to the daily routine CXRs, available for review by attending physicians. If a clinically indicated CXR was obtained between 4:00 AM and 8:00 AM, a daily routine CXR was not obtained. The attending physician could always order a new CXR even if a daily routine CXR was obtained shortly before. It was left to the discretion of the attending physician whether the daily routine CXR would suffice. If it did, that CXR became available for review (and was scored as "clinically indicated" for the purpose of the study analysis); if it did not, a new clinically indicated CXR was performed.

All CXRs were evaluated by trained radiologists before 8:30 AM. The radiologist interpreted all CXRs for the presence of predefined radiologic findings, categorized them as minor or major, and recorded whether they were new or old. In case of a life-threatening finding on a daily routine CXR, such as tension pneumothorax, the physician was notified immediately and that specific CXR was released for view in the PACS. Every morning, at the interdisciplinary meeting in the radiologic department, all clinically indicated CXRs of the previous 24 h were discussed. In addition, daily routine CXRs with unexpected, major predefined radiographic findings were shown by the radiologist, discussed with the physician, and released for view in PACS. A change in patient management that had been started based on CXR findings was recorded.

Data Collection

To evaluate the CXRs, two different request forms were designed. The form for the daily routine CXRs was divided into three parts. The first part contained the patient data and was filled in by the ICU nursing staff before the daily routine CXR was performed. It contained the date and time and the patient's name, age, and hospital number. Also, the clinical diagnosis and respiratory management of the patient (*eg*, intubation and mechanical ventilation) was recorded. The second part was the radiologic section of the form, and it contained a number of predefined possible radiographic findings, as defined in Table 1. Each finding was subdivided into three categories of severity: (1) new or progressive major findings, (2) new or progressive minor findings, or (3) unchanged, improved, or normal CXR findings. In particular, pulmonary edema was not included on the list of major predefined abnormalities because its presence was judged to be inferred from clinical data, such as physical examination, vital signs, fluid balance, and oxygen saturation. If the radiographic finding noticed by the radiologist was a new or progressive major finding and unsuspected by the physician, a specific box was ticked. The third part contained a list of predefined possible patient-management decisions including changes in medication or ventilator settings, repositioning of the endotracheal tube, IV catheters or chest tubes, bronchoscopy, insertion of a chest tube, surgical intervention, request for additional imaging studies, or no intervention or unchanged continuation of patient management. To assess actual changes in patient management, these changes in management were discussed and scored during the next interdisciplinary meeting with radiologists.

Diagnostic and Therapeutic Efficacy

To determine the value of the daily-routine CXRs, we used the two categories of efficacy defined by the American College of Radiology committee on efficacy.[13] Diagnostic efficacy (DE) [the number of CXRs with a new or progressive major finding divided by the total number of CXRs] is an indicator of the value of the CXR in assisting in a diagnosis. Therapeutic efficacy (TE) [the

Table 1—*Definitions of Predefined Radiologic Findings*

Cardiopulmonary Findings	Major Finding	Minor Finding
Atelectasis	> 2 lobes	< 2 lobes
Infiltrates	New or progressive	
Pleural effusion	> 1/2 thorax	< 1/2 thorax
Pulmonary edema		Any severity
Pneumothorax	Always	
Pneumomediastinum/pneumopericardium	New or progressive	
Subcutaneous emphysema	New or progressive	
Mediastinal abnormality	Significant widening	
Devices		
Malposition of tube	< 2 cm superior to the carina	
Malposition of central venous catheters	Tip outside lumen or change in position	
Malposition of pulmonary artery catheter	Distal from proximal interlobar pulmonary artery branch	
Malposition of chest tube	Outside thorax	
Malposition of nasogastric tube	Tip < 10 cm in stomach	

number of CXRs resulting in a change in clinical management divided by the total number of CXRs] is an indicator of the influence of the CXR on the patient's clinical management. Patients were subclassified into subcategories on the basis of their ventilatory status (intubated and mechanically ventilated or not), admission type (acute surgical, elective surgical, or medical), and ICU LOS: short stay (1 to 2 days), intermediate stay (3 to 14 days), and long stay (> 14 days).

Implementation Phase

Following the 1-year study period, the daily routine CXR strategy was abandoned (*ie*, all CXRs required a clinical indication, with no standing orders). For a half-year period, CXR volume data were collected, and ICU LOS, readmission rate, and mortality were compared with the preceding 1-year study period. Also, costs reductions were evaluated.

Costs

The costs of each CXR on the ICU were calculated at €46,50 per CXR, which is the amount reimbursed by the health insurance company for the costs of used materials, time spent by laboratory personnel, as well as time of the radiologist to interpret and report CXR findings.

Statistical Analysis

Data were entered into a computerized database (Microsoft Access 2000; Microsoft; Redmond, WA). Demographic and clinical data were extracted from the ICU database. All data are expressed as median with interquartile range (IQR) unless stated otherwise. Differences between groups were compared with χ^2 analysis using statistical software (SPSS version 13.0; SPSS; Chicago, IL); $p \leq 0.05$ was judged to indicate statistical significance.

Results

During the 1-year study period, 559 hospital admissions in 486 patients were evaluated. Demographics and clinical characteristics are summarized in Table 2. A total of 1,780 daily routine CXRs were evaluated. The median number of daily CXRs per patient per day was 1.0 (IQR, 0.88 to 1.16), including both daily routine CXRs (n = 1,780) and clinically indicated CXRs (n = 907). There were no differences when patients were stratified for ventilatory status (not intubated and not receiving mechanical ventilation vs receiving mechanical ventilation) or admission type (acute surgical, elective surgical, or medical).

Table 2—*Patient Demographics and Clinical Characteristics**

Variables	Study Period	Implementation Period
Patients, No.	486	250
Male gender, No. (%)	281 (57.8)	142 (56.8)
Age, yr	71 (59–78)	67 (54–76)
Admissions, No.	559	274
Readmissions, No. (%)	73 (13)	24 (9)
Hospital mortality, No. (%)	79 (16)	38 (14)
APACHE II score	14 (11–20)	13 (9–19)
APACHE II predicted mortality, %	16.1 (7.9–31.7)	15.2 (8.2–28.8)
Type of admission, No. (%)		
Acute surgery	145 (26)	76 (28)
Elective surgery	138 (25)	76 (28)
Medical	276 (49)	122 (44)
Ventilatory status, No. (%)		
Not ventilated	224 (40)	96 (35)
Ventilated	335 (60)	178 (65)
ICU LOS, No. (%)		
1–2 d	341 (61)	176 (65)
3–14 d	179 (32)	83 (30)
≥ 15 d	39 (7)	15 (5)

*APACHE = acute physiology and chronic health evaluation. Values are expressed in median (25 to 75th percentile) unless stated otherwise. All statistical comparisons between both groups are not significant.

DE of Routine CXRs

Of all daily routine CXRs, 79 of 1,780 CXRs (4.4%) revealed predefined new or progressive major findings. Specific data, including those in clinically indicated CXRs, are shown in Table 3. The occurrence of major findings was not related to ventilatory status: not ventilated vs ventilated, 19 of 499 CXRs (3.8%) vs 60 of 1,281 CXRs (4.7%), respectively [p = not significant]; or admission type: acute surgery, 19 of 556 CXRs (3.4%); elective surgery, 10 of 267 CXRs (3.7%); or medical, 50 of 958 CXRs (5.2%) [p = not significant].

TE of Routine CXRs

Of all daily routine CXRs, 33 of 1,780 CXRs (1.9%) resulted in a change in clinical management. Specific data, including those in clinically indicated CXRs, are shown in Table 4. Total TE was not related to ventilatory status or admission type. The most frequent therapeutic change after a routine CXR was repositioning of the oropharyngeal tube, whereas a clinically indicated CXR led most frequently to a change in medication. In four cases, CXRs were made available by the radiologist with abnormalities other than those predefined. These included ileus, thoracic position of the stomach, free air below the diaphragm, and the presence of large lymphomas. In those four cases, the only CXR directly leading to an action was the presence of lymphomas, *ie*, a CT scan was planned after discharge from the ICU). In the other cases, patients had undergone laparatomy in the meantime (*ie*, the decision to perform surgery was not related to CXR findings).

Table 3—*DE Based on Major Findings

Variables	Routine CXR (n = 1,780)	Clinically Indicated CXR (n = 907)
Any major finding	79 (4.4)	138 (15.2)†
Infiltrate	34 (1.9)	45 (4.9)
Malposition of oropharyngeal tube	13 (0.7)	32 (3.5)
Pneumothorax	10 (0.5)	22 (2.4)
Pleural effusion	7 (0.4)	13 (1.4)
Malposition of IV line	9 (0.5)	14 (1.5)
Atelectasis	4 (0.2)	13 (1.4)
Malposition of thorax tube	1 (0.1)	1 (0.1)
New subcutaneous emphysema	1 (0.1)	0
Severe widened mediastinum	0	0
Malposition of nasogastric tube	0	0
Other	4 (0.2)	17 (1.8)
Any major or minor finding	335 (18.8)	251 (27.7)†

*Data are presented as No. (%).
†p < 0.001.

Table 4—*TE Based on Major Findings

Variables	Routine CXR (n = 1,780)	Clinically Indicated CXR (n = 907)
Any change in management	33 (1.9)	162 (17.9)†
Adjustment of oropharyngeal tube	10 (0.6)	26 (3.0)
Bronchoscopy	3 (0.2)	13 (1.4)
Change in medication	4 (0.2)	38 (4.2)
Adjustment of IV line	4 (0.2)	14 (1.5)
Adjustment of thorax tube	0	6 (0.7)
Placement of thorax tube	3 (0.2)	9 (1.0)
Control follow-up CXR	2 (0.1)	7 (0.8)
Change in respiratory settings	0	12 (1.3)
Other	12 (0.7)	42 (4.9)

*Data are presented as No. (%).
†p < 0.001.

Implementation Phase

In the implementation phase, 433 CXRs during 274 admissions in 250 patients were evaluated. The total number of CXRs per patient per day, including both routine and clinically indicated radiographs, declined from 1.0 CXRs (IQR, 0.88 to 1.16) during the study period, to 0.50 CXRs (IQR, 0.33 to 0.57) during the implementation phase (Fig 1). The number of clinically indicated CXRs per patient per day (0.50; IQR, 0.29 to 0.69) during the study period equals the number of clinically indicated CXR per patient per day after abandoning the daily routine CXR. ICU LOS did not differ between both periods; neither did the readmission rate or hospital mortality (Table 2).

Costs

The reduction in the number of CXRs per patient per day resulted in a reduction of €82,500 (approximately $99,000/yr [US dollars]).

Discussion

This is the first blinded study evaluating the efficacy of daily routine CXRs in the ICU. The results confirm and corroborate previous data indicating that the diagnostic yield and therapeutic consequences of daily routine CXRs are very low. Furthermore, abolishing a daily routine CXR strategy did not affect ICU LOS, readmission rate, and hospital mortality

New and unsuspected clinically relevant abnormalities were found in only 4.4% of daily routine CXRs. Less than half of these induced a change in patient management. The necessity of this change could not be inferred from clinical, laboratory, or ventilator data. Of note, since probably only major

findings are of clinical relevance, we based the diagnostic efficacy on these findings, which is comparable to other studies.[11,14] Graat et al[11] prospectively evaluated 2,457 routine CXRs in an academic tertiary referral ICU, of which 5.8% revealed unexpected major findings. However, the nature of the radiographic pathology missed on clinical grounds is important. Our blinded study design enabled us to register this pathology after the daily clinical rounds in the ICU. The most frequently missed radiographic pathology was a new or progressive infiltrate, which may not be clinically relevant because CXR findings carry a low sensitivity (0.62) and specificity (0.28) for the diagnosis of pneumonia in the ICU.[15] Also, patients may already receive antibiotics. Malposition of the oropharyngeal tube, defined as < 2 cm above the carina, should be corrected but may lead to pulmonary problems in only a minority of cases. The most important radiographic finding potentially influencing therapeutic actions is a pneumothorax, particularly in patients receiving mechanical ventilation. Our study overestimated their incidence because we not only counted the new or progressive, but also the persisting ones. Most were related to the introduction of a central venous catheter. However, the vital signs of all patients are closely monitored in the ICU, and when a serious deterioration in vital signs occurs, it is promptly noted and a CXR can be ordered instantly.

DE or TE of the daily routine CXR did not change when specific subgroups were analyzed, such as ventilated vs not ventilated, ICU LOS, or patient type (acute or elective surgical or nonsurgical). These findings also concur with previous data.[12] Also, LOS, readmission rate, and hospital mortality, as well as the number of clinically indicated CXRs per patient per day did not change during the implementation phase. This is in agreement with Krivopal et al,[10] who performed a randomized controlled study comparing daily routine CXRs with a strategy based on clinical indication. Although they demonstrated that ICU LOS and mortality did not differ between both strategies, the study was too small to draw firm conclusions. Price at al[9] demonstrated in a small, nonrandomized controlled study that abolishing daily routine CXRs in a pediatric ICU resulted in fewer CXRs per patient per day while LOS ICU remained unchanged. Brainsky et al[16] showed findings on 33% of all routine CXRs. In 20% of all CXRs, findings were judged to be important; in 8% of all CXRs, findings prompted actions. In the study by Marik and Janower,[8] a change in therapy was made based on information obtained from the CXR in 37% of radiographs. Most frequent therapeutic interventions were use of a loop diuretic to treat pulmonary edema (26%), repositioning of an endotracheal tube (24%), and diagnostic studies to determine the cause of a new pulmonary infiltrate (16%). The most recent study was performed in an academic ICU describing DE and impact on therapy in a period before and after the abolishment of daily routine CXRs.[12] Although findings were remarkably comparable to our data, a major drawback in their study is the absence of a strict way to determine potential complications as a result of abolishing daily-routine CXRs.

There are several limitations to our study that should be mentioned. Although the daily routine

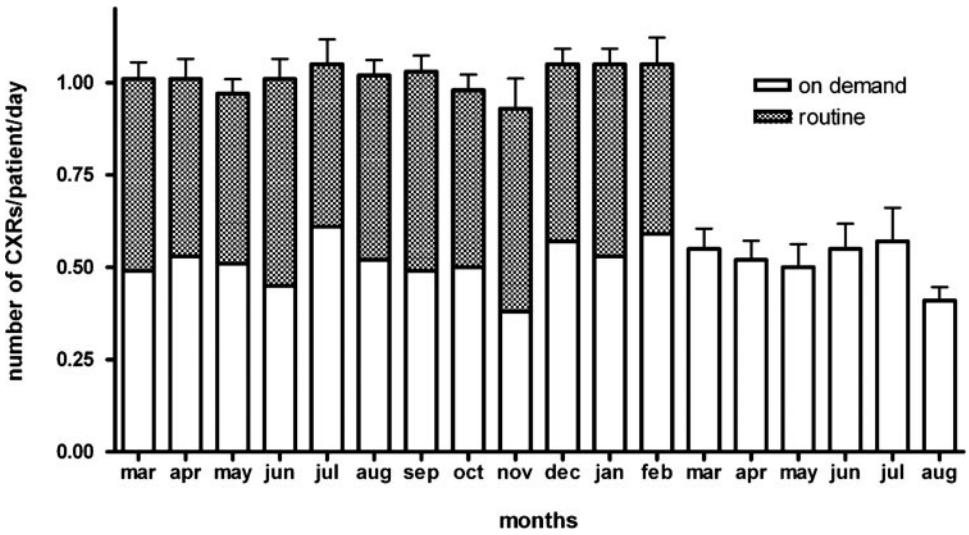

FIGURE 1. Mean number of daily-routine and clinically indicated CXRs per patient per day over time before and after abolishing daily-routine CXRs. Whiskers indicate SEM.

CXRs were not accessible for attending physicians, the decision to order a CXR could have been influenced by the assurance not to miss important findings, because of the protocolized warning of the radiologist in case a predefined major radiologic finding would occur. However, we consider this less likely because the number of clinically indicated CXRs did not change in the implementation phase. Furthermore, this is a single-center study with dedicated and trained radiologists, which may hamper implementation of this strategy in other hospitals with differences in and case mix and staffing, especially during off-hours. However, data from an academic hospital in the Netherlands with larger staffing demonstrated comparable results.[11] Furthermore, this study was not designed or powered to detect differences between the study period and the implementation phase with respect to mortality, ICU LOS, readmission rate, and costs. Finally, we have not randomized the study population in a daily routine and a clinically indicated group, which would have yielded data such as patient survival in the two study regimens. However, that study design would not have allowed us to register the pathology that was clinically missed.

Since we and others[12] demonstrated that $< 5\%$ of the daily routine CXRs show unexpected major abnormalities, of which only one third have therapeutic consequences directly related to the CXR itself, we consider it safe to abandon the daily routine CXR strategy in an ICU environment. Calculations based on CXR volume demonstrated that the change in ordering CXR resulted in considerable cost savings. In addition, radiation exposure is decreased by eliminating unnecessary CXRs, which may particularly count for long-stay patients.

We conclude that the diagnostic yield of the daily routine CXR is low for all ICU patients and rarely initiates therapeutic changes. In addition, we showed that a change in ordering CXR did not affect patient outcome.

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