

On-demand Rather than Daily-routine Chest Radiography Prescription May Change Neither the Number Nor the Impact of Chest Computed Tomography and Ultrasound Studies in a Multidisciplinary Intensive Care Unit

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Background: **Elimination of daily-routine chest radiographs (CXRs) may influence chest computed tomography (CT) and ultrasound practice in critically ill patients.**

Methods: **This was a retrospective cohort study including all patients admitted to a university-affiliated intensive care unit during two consecutive periods of 5 months, one before and one after elimination of daily-routine CXR. Chest CT and ultrasound studies were identified retrospectively by using the radiology department information system. Indications for and the diagnostic/therapeutic yield of chest CT and ultrasound studies were collected.**

Results: **Elimination of daily-routine CXR resulted in a decrease of CXRs per patient day from 1.1 ± 0.3 to 0.6 ± 0.4 ($P < 0.05$). Elimination did not affect duration of stay or mortality rates. Neither the number of chest CT studies nor the ratio of chest CT studies per patient day changed with the intervention: Before elimination of daily-routine CXR, 52 chest CT studies were obtained from 747 patients; after elimination, 54 CT studies were obtained from 743 patients. Similarly, chest ultrasound practice was not affected by the change of CXR strategy: Before and after elimination, 21 and 27 chest ultrasound studies were performed, respectively. Also, timing of chest CT and ultrasound studies was not different between the two study periods. During the two periods, 40 of 106 chest CT studies (38%) and 18 of 48 chest ultrasound studies (38%) resulted in a change in therapy. The combined therapeutic yield of chest CT and ultrasound studies did not change with elimination of daily-routine CXR.**

Conclusions: **Elimination of daily-routine CXRs may not affect chest CT and ultrasound practice in a multidisciplinary intensive care unit.**

CHEST radiographs (CXRs) are frequently obtained as a complement to physical examination of intensive care unit (ICU) patients.[1,2] A strategy in which CXRs are obtained routinely and without specific reasons (a so-called daily-routine strategy) is widely practiced because of the reported high prevalence of findings on CXR in critically ill patients.[3,4] Unfortunately, in most studies on daily-routine CXR, no discrimination is made between clinically relevant and irrelevant findings.[5] We recently demonstrated that daily-routine CXRs hardly ever reveal potentially important abnormalities and, more importantly, seldom result in a change in therapy.[6] Several studies now suggest that a strategy in which every CXR requires an indication (a so-called on-demand strategy) may be equally good as a routine strategy.[7–10] Accordingly, we changed the CXR strategy in our department.

In our department, it was wondered whether the changed CXR strategy affected chest computed tomography (CT) and ultrasound practice, because these studies are frequently triggered by (new) findings on CXR. It was hypothesized that not performing daily-routine CXR could result in a decline in the number of these studies. If this decline in studies causes oversight of important pathology, this may lead to longer durations of stay in the ICU, higher readmission rates, and even higher mortality rates. In addition, because an on-demand strategy may result in a delay of finding abnormalities on CXR triggering chest CT or ultrasound studies, the elimination of daily-routine CXR may also result in these studies being performed at later time points during the stay in the ICU.

To evaluate the impact of the elimination of daily-routine CXR on chest CT and ultrasound practice, we determined the number of these studies during two periods: 5 months before and 5 months after elimination of daily-routine CXR. In addition, we determined timing, indications, and the diagnostic and therapeutic efficacy of chest CT and ultrasound studies before and after this intervention.

Materials and Methods

Setting

The study was conducted in a 28-bed closed-format multidisciplinary ICU of a university hospital, in which medical and surgical patients (including cardiothoracic surgery patients and neurosurgery patients) are under the direct care of the ICU team. The ICU team comprises 8 full-time intensivists, 8 subspecialty fellows, and 12 residents. All beds are equipped with a patient data

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management system (Metavision; iMDsoft, Sassenheim, The Netherlands). The study protocol was approved by the local ethics committee (Medical Ethical Committee of the Academic Medical Center, Amsterdam, The Netherlands); informed consent was not deemed necessary because of the retrospective, observational nature of this study.

Design

The study period was divided into two parts. In phase 1, a 5-month phase (March 2004 to July 2004), daily-routine CXRs were made between 8:00 and 9:00 AM each day (*i.e.*, standing orders for all patients). After tracheal extubation, CXRs were only made if clinically indicated, except for cardiothoracic surgery patients on the first postoperative day. Only if an on-demand CXR was performed within 4 h before the morning round was no daily-routine CXR made. It was the unit policy to obtain additional (*i.e.*, on-demand) CXR only after insertion of central venous lines, an intraaortic balloon pump, or tracheal and chest tubes, or when a patient encountered an increase in oxygen requirement or had a change in pulmonary secretions with or without fever. CXRs were never made to check the position of a nasogastric tube after insertion. In phase 2, a 5-month phase (September 2004 to January 2005) that began 1 month after elimination of daily-routine CXR, there were no standing orders for daily-routine CXRs, and each CXR required a clinical indication (*i.e.*, insertion of new devices, increase oxygen requirement, or change in pulmonary secretions with or without fever).

Chest radiograph and chest CT and ultrasound studies were only ordered by ICU physicians (*i.e.*, staff ICU physicians, ICU fellows, and ICU residents; of note, additional radiology studies always required approval by the attending staff ICU physician).

Chest CT studies required transport of the patient to the radiology department; all chest ultrasound studies were performed at the bedside and always by radiologists.

All CXR, chest CT, and ultrasound studies were interpreted by an independent radiologist on the day the study was performed; the radiologist communicated any positive findings on daily-routine CXR during a daily meeting with ICU physicians at 10:00 AM. Findings on chest CT and ultrasound studies were communicated directly with the attending physician.

Data Collection

From all of the patients, the following data were recorded: age, sex, Acute Physiology and Chronic Health Evaluation II score (first 24 h of admission), type of ICU admission, ICU duration of stay, and ICU mortality/hospital mortality.

Radiologic Data

All radiologic data (number, timing, indications, and yield) were automatically collected retrospectively from our radiology department information system.

Indications for CT and ultrasound studies were collected from the hospital information system and classified. It is hospital policy that every CT and ultrasound study include a written form stating the reason for and expectancies of the study requested by the attending physician; such forms are scanned before each study and stored in the hospital information system.

The findings of chest CT and ultrasound studies were collected from the hospital information system and classified. To determine the true therapeutic yield of chest CT and ultrasound studies, the patient data management system was carefully checked for sputum culture orders, bronchoscopy and bronchoalveolar lavage culture, and/or start of antimicrobial therapy aiming at respiratory infection (in case of infectious infiltrations); insertion of a pleural drain (in case of pleural fluid or pneumothorax); and changes in levels of positive end-expiratory pressure or physiotherapy (in case of atelectasis).

Definitions

The indications for ordering CT studies by members of the ICU team were classified into four categories: evaluation of abnormalities seen on CXR, a change in clinical status, follow-up of a previously found abnormality, and CT guidance of intrathoracic puncture or drain insertion. Indications for ultrasound studies were classified into two categories: abnormality suspect for pleural effusion seen on CXR and subsequent drain insertion, and a change in clinical status.

In addition, findings on both CT and ultrasound studies were classified as "not expected but found" when the finding was not mentioned on the accompanying request form, "expected and found" when the finding was mentioned and found, and "expected but not found" when the abnormality mentioned on the accompanying request form was not found by the radiologist.

Statistics

Descriptive statistics were used to compare patient characteristics. Data are expressed as median [interquartile range]. A Mann–Whitney U test was used for analyzing continuous variables. In case of nominal data, chi-square analysis was used. A statistical software package (Statistical Package for the Social Sciences, version 12; SPSS Inc., Chicago, IL) was used for the statistical analyses. $P < 0.05$ was considered to indicate statistical significance.

Table 1. Demographic Data

	Period 1: Daily-routine Strategy	Period 2: On-demand Strategy	*P* Value
Patients, n	747	743	
ICU admissions	807	825	
Age, median [IQR], yr	62 [49–72]	64 [50–72]	0.308
Male sex, n (%)	471 (56.8)	453 (53.7)	0.407
APACHE II score, median [IQR]	15 [12–20]	15 [11–20]	0.872
Patient ICU admission subgroups, n (%)			
Cardiothoracic surgery	340 (42.1)	336 (40.7)	0.565
Medical	195 (24.2)	168 (20.4)	0.065
Surgical	153 (19.0)	191 (23.1)	0.038
Neurosurgical/neurology	97 (12.0)	106 (12.9)	0.612
Other	22 (2.7)	24 (2.9)	0.823
CXRs while being intubated and mechanically ventilated	3194 (82)	1115 (88)	<0.001
Duration of stay in ICU, median [IQR], days	2 [1–4]	2 [1–4]	0.495
Mortality			
ICU, n (%)	87 (10.8)	81 (9.8)	0.386
Hospital, n (%)	128 (15.9)	141 (17.1)	0.482

Daily-routine strategy: standing orders for chest radiographs; on-demand strategy: each chest radiograph (CXR) required a specific indication.

APACHE = Acute Physiology and Chronic Health Evaluation; ICU = intensive care unit; IQR = interquartile range.

Results

Study Population

We evaluated 1,632 admissions in 1,490 patients during the two consecutive study periods (807 admissions in 747 patients and 825 admissions in 743 patients) before and after elimination of daily-routine CXR, respectively. In the first period, the sum of all nursing days from all admissions was 4,148 days, and that in the second period was 4,475 days. The patient profiles on entering this study and the assembly of the subgroups of the admissions are presented in table 1. In the second period, more surgical patients were admitted than in the first period ($P < 0.05$). The majority of studies were performed in medical and surgical patients (table 2). Patients with chest CT and/or ultrasound studies had a longer ICU duration of stay than patients without chest CT and/or ultrasound studies during stay in the ICU. Elimination did not affect duration of stay or mortality.

Radiologic Volume Data

Adjusting for patient volume, the ratio of CXR per patient day decreased from 1.1 ± 0.3 to 0.6 ± 0.4 after the intervention ($P < 0.05$). The median number of CXRs per patient for the complete stay in the ICU declined from 3 (range, 2–5) in phase 1 to 1 (range, 1–2) in phase 2.

Table 2. Performance of CT and Ultrasound Studies in the ICU during Two Different Periods, before and after Intervention

	CT			Ultrasound		
	Period 1: Daily-routine Strategy	Period 2: On-demand Strategy	*P* Value	Period 1: Daily-routine Strategy	Period 2: On-demand Strategy	*P* Value
Patients with CT or ultrasound study, n	38	44	0.479	19	17	0.748
Cardiothoracic surgery, n (%/%)	2 (0.6/5.3)	5 (1.5/11.4)	0.324	5 (1.5/11.4)	7 (2.1/41.2)	0.345
Medical, n (%/%)	19 (9.7/50.0)	13 (7.7/29.5)	0.058	10 (5.1/52.6)	3 (1.8/17.6)	0.029
Surgical, n (%/%)	15 (9.8/39.4)	25 (13.1/56.8)	0.117	3 (2.0/15.8)	6 (3.2/35.3)	0.177
Neurosurgical/neurology, n (%/%)				1 (5.3%)	—	0.337
Other, n (%/%)	2 (8.3/5.3)	1 (4.0/2.3)	0.472	—	1 (4/5.9)	0.284
Total number of studies	52	54	0.923	21	27	0.471
Number of studies per 100 nursing days	1.25	1.21		0.51	0.60	
Total duration of stay in ICU, patients with CT or ultrasound study, median [IQR], days	10 [6–18]	10 [5–25]	0.722	12 [4–29]	24 [4–46]	0.563
Duration of stay in ICU at time of study, median [IQR], days	4 [1–9]	3 [0–8]	0.306	2 [1–9]	6 [1–28]	0.069
Time between last CXR and CT, median [IQR], h	3 [2–6]	21 [7–53]	0.000	6 [4–7]	13 [7–33]	0.000

% = percentage patients with a computed tomography (CT) or ultrasound study of total number of patients in the specified category; % = percentage patients with a CT or ultrasound study of total number of patients with a CT or ultrasound study. *P* values indicate difference between the two periods.

CXR = chest radiograph; ICU = intensive care unit; IQR = interquartile range.

During the two periods, 108 chest CT studies were made in 82 patients: 40 surgical patients, 32 medical patients, 7 cardiothoracic surgery patients, and 3 neurosurgical/neurology patients. The number of chest CT studies did not change with the change in CXR strategy; a total of 52 (range, 1–4 per patient) chest CT studies in 38 patients and 54 (range, 1–4 per patient) chest CT studies in 44 patients were performed before and after the intervention, respectively (table 2). In accord, the number of CT studies per 100 nursing days did not differ between the two periods.

During the two periods, 48 ultrasound studies were performed in 36 patients: 13 medical patients, 12 cardiothoracic surgery patients, 9 surgery patients, 1 neurosurgical/neurology patient, and 1 patient from the ear, nose, and throat department. The number of ultrasound studies did increase slightly from 21 (range, 1–2 per patient) ultrasound studies in 19 patients to 27 (range, 1–3 per patient) ultrasound studies in 17 patients in the two consecutive periods, but the difference did not reach statistical significance (table 2). In accord, the number of studies per 100 nursing days did not increase. In the first period, more medical patients had an ultrasound study than in the second period ($P < 0.05$).

Timing of Chest CT and Ultrasound Studies

There were no differences between the two study periods regarding the timing of CT and ultrasound studies during stay in the ICU. In the first period, CT studies were performed 4 [1–9] days after admission to ICU and ultrasound studies were performed after 2 [1–9] days. In the second period, CT studies were performed after 3 [0–8] days and ultrasound studies were performed after 6 [1–28] days. Not surprisingly, the time between CXR before each CT study or ultrasound study and the actual performance was different between the two periods ($P < 0.05$): Before elimination of daily-routine CXR in this period, the time between studies was never longer than 24 h, because a daily-routine CXR was performed every morning in these patients.

Indications for Chest CT and Ultrasound Studies

In 58 cases, the indication for a chest CT study was a change in the clinical status (in 26 and 32 cases in periods 1 and 2, respectively); in 37 cases, the main indication was follow-up of a previously found abnormality (19 and 16 cases); in 9 cases, a chest CT study was performed to evaluate an abnormality seen on the CXR (5 and 4 cases); in 2 cases, a chest CT study was obtained for CT guidance of an intrathoracic puncture or insertion of a drain (1 in each period). In 40 cases, the indication for an ultrasound study was an abnormality on the CXR (17 and 23 cases in period 1 and 2, respectively); in 8 cases, the indication was a change in clinical status (4 in both periods). None of the differences between the two periods reached statistical significance.

Diagnostic and Therapeutic Yield of CT and Ultrasound Studies

The diagnostic yield of the studies is presented in table 3. The four most common findings on the 106 chest CT studies were pleural effusions (n = 23; 12 surgical pa-

Table 3. Findings of the CT and Ultrasound Studies

	CT			Ultrasound		
	Period 1: Daily-routine Strategy	Period 2: On-demand Strategy	*P* Value	Period 1: Daily-routine Strategy	Period 2: On-demand Strategy	*P* Value
Unexpected but found, n (%)	14 (27)	13 (24)	0.736	0	3 (11)	0.115
Pleural effusions	5	5		—	2	
Pneumothorax	2	2		—	—	
Infiltrations	4	5		—	—	
Abscesses	—	—		—	1	
Atelectasis	1	1		—	—	
Pulmonary embolism	1	—		—	—	
Hematoma	1	—		—	—	
Expected and found, n (%)	31 (60)	29 (54)	0.539	11 (52)	16 (60)	0.634
Pleural effusions	8	5		10	14	
Pneumothorax	7	4		—	1	
Infiltrations	3	5		—	—	
Abscesses	5	1		—	—	
Atelectasis	1	4		1	1	
Pulmonary embolism	1	1		—	—	
Aneurysm	2	—		—	—	
Aorta dissection	2	5		—	—	
Malignancies	2	2		—	—	
Other*	—	2		—	—	
Expected but not found, n (%)	4 (8)	8 (15)	0.247	7 (33)	6 (22)	0.390

% = percentage of total number of patients with a computed tomography (CT) or ultrasound study. *P* values indicate difference between the two periods.

* Includes contusion and fibrosis.

Table 4. Findings Resulting in a Change in Therapy

	CT			Ultrasound		
	Period 1: Daily-routine strategy	Period 2: On-demand strategy	*P* Value	Period 1: Daily-routine strategy	Period 2: On-demand strategy	*P* Value
Change in therapy, n (%)	25 (48)	15 (30)	0.031	5 (24)	13 (48)	0.084
Pleural effusions	9	4		5	12	
Pneumothorax	6	1		—	—	
Infiltrations	3	4		—	—	
Abscesses	2	1		—	—	
Atelectasis	1	3		—	1	
Pulmonary embolism	2	1		—	—	
Aneurysm	1	—		—	—	
Malignancies	1	—		—	—	
Contusion	—	1		—	—	

% = percentage of total number of patients with a computed tomography (CT) or ultrasound study. *P* value indicates difference between the two periods.

tients, 9 medical patients, 2 other), infiltrations (n = 17; 8 surgical patients, 9 medical patients), pneumothorax (n = 15; 9 surgical patients, 6 medical patients), and abscesses (n = 7; 6 surgical patients, 1 medical patient); in 12 cases, no abnormalities were found. The two most common findings on 48 ultrasound studies were pleural effusions (n = 27; 10 cardiothoracic surgery patients, 8 surgical patients) and pulmonary atelectasis/consolidation (n = 5).

During the complete study period, 40 of 106 chest CT studies (38%) and 18 of 48 chest ultrasound studies (38%) resulted in any change in therapy (table 4). Before the intervention, more CT studies resulted in a change in therapy ($P < 0.05$). Fourteen chest CT studies were originally performed of the abdomen, but the thorax was scanned in addition (*i.e.*, the CT study was primarily performed to evaluate the abdominal cavity). Two of 5 of these CT studies in the first period and 3 of 9 in the second period resulted in a change in therapy. The combined therapeutic yield of chest CT and ultrasound studies did not change with elimination of daily-routine CXR.

Discussion

Our study demonstrates that the impact of elimination of daily-routine CXR on chest CT and ultrasound practice is minimal in a multidisciplinary ICU. No decrease in the number of CT and ultrasound studies or important differences in clinical indications and diagnostic yield were found. Also, abandoning daily-routine CXR did not delay chest CT and ultrasound studies during the stay in the ICU. This is the first study in which the impact of the elimination of daily-routine CXRs on chest CT and ultrasound practice has been studied.

Our findings are in accord with a previous report from our group.[10] Although findings on daily-routine CXR may trigger CT or ultrasound studies, these CXR hardly ever reveal clinically important abnormalities.[6] In contrast, the diagnostic value of on-demand CXR is high, at least higher as compared with daily-routine CXR. Abandoning daily-routine CXR, therefore, might not influence CT or ultrasound study practice. This is what we found in the current analysis. However, an on-demand strategy may result in a delay of finding abnormalities on CXR, thereby delaying CT or ultrasound studies. This was, however, not found in the current analysis.

Although we expected that the two periods would be balanced regarding the demographic data, in particular with respect to admittance category, there was some imbalance: While in the first period more medical patients were admitted, surgical patients outnumbered medical patients after the change in CXR practice. In addition, in the first period, more CT studies were performed in medical patients than in the second period, during which most of the patients with a CT study were surgical. The difference in therapeutic yield of CT studies between the two periods may in part be explained by these two differences: Pleural effusions and infiltrations (which were seen equally in medical and surgical patients) more easily trigger a therapeutic intervention (*i.e.*, drainage, culture studies and/or start of antimicrobial therapy) than, for example, abscesses (which were seen mostly in surgical patients). Another explanation could be the decline in the number of pneumothoraces, which resulted in a change of therapy. What can be suggested is that with an on-demand CXR strategy, in some cases pneumothoraces are simply missed. The number of CT studies in our study, however, is too low to draw firm conclusions. Finally, while the types of interventions were grossly the same (merely pleural drainage), the comparison could be done with a combination of chest CT and ultrasound studies. With this respect, the reduction in the therapeutic yield of chest CT studies may not be a coincidence, but the result of a larger use of ultrasound studies.

Because this study is retrospective in its design, one limitation is that we did not incorporate a prospective definition of indications, as well as a brief template recording the answer to the study questions. However, at our institution, radiologists are explicit in what information clinicians must give before chest CT and ultrasound studies are to be performed. Only incidentally is all information not presented in the written form. The same applies for intensivists, who request written reports on all CT and/or ultrasound studies by radiologists. Furthermore, in our patient data management system, therapeutic consequences of any radiology study are almost always mentioned or are easily found. A second limitation is the lack of insight on how clinicians make decisions about when to order additional radiology studies. The design of our study does not allow any conclusions in this respect; additional studies are needed to address this issue. Therefore, we cannot address how decision making may have changed with the change in strategy.

Our data are in accord with other publications on chest CT and ultrasound studies in critically ill patients.[11–14] Interestingly, during the two study periods, the therapeutic yield of both CT and ultrasound studies was low: Less than 40% of these studies resulted in a change in therapy. Of note, however, also a "negative" study at times can be considered to be of clinical interest. Indeed, ruling out the presence of an abnormality is maybe as important as the finding of an abnormality. The design of our study did not allow us to score for this.

Although findings on chest CT studies may also trigger chest ultrasound studies (*e.g.*, finding pleural effusion on a chest CT study, for which at a later time point a chest ultrasound study is performed to guide drain insertion), this was only found once in our cohort.

It was recently shown that abandoning daily-routine CXR in the ICU reduces healthcare costs[9,15] without adverse clinical consequences.[15] Abandoning daily-routine CXR from daily practice in our ICU did not lead to a change in duration of stay, nor did it affect survival. We also showed a significant cost reduction with this change in practice. Indeed, in our 28-bed ICU, cost reduction was approximately €19.000 per month.[10] Because neither the number and timing of chest CT and ultrasound studies during the two periods nor the diagnostic/therapeutic value of CT and ultrasound studies changed with abandoning daily-routine CXR, we consider our findings as another argument in favor of the on-demand CXR strategy currently practiced in our ICU.

We consider the decrease in therapeutic yield of chest CT studies with the abandoning of daily-routine CXRs in our study to be a coincidence. We consider it important to mention, however, that results that come from one center may not simply apply for other centers. In environments with high medicolegal liability, the elimination of the daily-routine CXR might be seen as harmful because of the danger of failing to act properly to treat a known problem. Also, differences in staffing and differences in case mix may be of great influence on outcome when abandoning daily-routine CXR.

In conclusion, elimination of daily-routine CXR may not affect the chest CT and ultrasound practice in a multidisciplinary ICU.

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