Abandoning Daily Routine Chest Radiography in the Intensive Care Unit: Meta-Analysis[1]

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Purpose: To systematically examine whether abandoning daily routine chest radiography would adversely affect outcomes, such as mortality and length of stay (LOS), and identify a subgroup in which daily routine chest radiography might be beneficial.

Materials and Methods: This was a meta-analysis of clinical trials that examined the effect of abandoning daily routine chest radiography in adults in intensive care units (ICUs). Studies were identified through searches of MEDLINE, Cochrane Database, Database of Abstracts of Reviews of Effects, Biological Abstracts, and CINAHL. The results were expressed as odds ratios (ORs) or weighted mean difference (WMD) along with their 95% confidence intervals (CIs).

Results: Eight studies with a total of 7078 patients were identified. A pooled analysis revealed that the elimination of daily routine chest radiography did not affect either hospital or ICU mortality (OR, 1.02;[95% CI: 0.89, 1.17; $P = .78$ and OR, 0.92; 95% CI: 0.76, 1.11; $P = .4$, respectively). There was no significant difference in ICU LOS (WMD = 0.19 days; 95% CI: −0.13, 0.51; $P = .25$), hospital LOS (WMD = −0.29 days; 95% CI: −0.71, 0.13; $P = .18$), and ventilator days (WMD = 0.33 days; 95% CI: −0.12, 0.78; $P = .15$) between the on-demand and daily routine groups. Regression analyses failed to identify any subgroup in which performing daily routine chest radiography was beneficial.

Conclusion: Systematic but unselective daily routine chest radiography can likely be eliminated without increasing adverse outcomes in adult patients in ICUs. Further studies are necessary to identify the specific patient population that would benefit from daily routine chest radiographs.

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It is common for a patient in the intensive care unit (ICU) to undergo chest radiography on a daily basis, especially those who are mechanically ventilated. Daily routine chest radiographs are obtained in an attempt to find a relevant abnormality that would otherwise not be detected. The American College of Radiology's Appropriateness Criteria (1) recommend daily chest radiography for patients with acute cardiopulmonary problems and for patients on mechanical ventilation. However, this practice has been scrutinized and may have little benefit (2,3). Results of previous studies (4–6) suggested that the abnormalities detected with daily routine radiography were relatively minor and unlikely to alter a clinical course in the majority of ICU patients.

Millions of ICU chest radiographs are ordered in medical centers across the United States each year (7). Obtaining daily routine chest radiographs is labor intensive. Moving critically ill patients to undergo chest radiography can be associated with problems and complications such as malpositioning of the device from obtaining the radiograph (8). An alternative strategy is to obtain chest radiographs only when clinically indicated, which may save healthcare costs, as well as reduce radiation exposure to staff and patients (2,5,9). We hypothesized that abandoning routine daily chest radiography would not adversely affect clinically important outcomes, such as mortality and ICU and hospital length of stay (LOS).

Our objectives were to systematically examine if abandoning daily routine chest radiography would adversely affect outcomes such as mortality and LOS and identify a subgroup in which daily routine chest radiography might be beneficial.

Materials and Methods

Identification of Trials

We identified all relevant clinical trials that compared the impact of daily routine chest radiography with that of clinically indicated chest radiography. Both authors independently searched the National Library of Medicine's Medline database for studies in any language published from January 1, 1950 to December 31, 2008 by using the MeSH headings and keywords: Radiography AND Intensive Care or Critical Care AND Outcome Assessment (Health Care) or Outcome and Process Assessment (Health Care) or Mortality or Length of Stay or Prognosis. In addition, we searched Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, Biological Abstracts and Cumulative Index to Nursing and Allied Health Literature (CINAHL). Bibliographies of all selected articles and review articles that included information on chest radiographs of adult ICU patients were reviewed for other relevant articles. We also reviewed our personal files and contacted experts in the specialty. This search strategy was done iteratively for 4 weeks until we did not find any new potential citations on review of the reference lists of retrieved articles.

Study Selection and Data Extraction

Both authors independently abstracted data from all studies by using a standardized form. Data were abstracted for study design, study size, population, severity of illness, and the effects of daily routine chest radiograph on the endpoints of interest. Disagreements regarding values or analysis were resolved by means of discussion.

To be included in our analysis, studies had to be randomized controlled or observational trials comparing outcome efficacy of daily routine versus clinically indicated chest radiographs of patients admitted to an adult medical or surgical ICU and had to have at least one of the following as a primary outcome variable: hospital or ICU mortality, length of mechanical ventilation or hospital stay, and adverse event rate. The adverse events included inadvertent extubations and reintubations, in-hospital complications requiring intervention, and readmissions to ICU. At least 30% of study patients should be mechanically ventilated to be included in the analysis. We did not set a minimum number of patients or duration of trial to be included in the study. Trials enrolling pediatric patients (<18 years of age) were excluded.

The quality of included studies was evaluated by using the CONSORT criteria for randomized controlled studies (10) and STROBE criteria for observational studies (11). Each study was given a score on a scale from 1 to 22, reflecting how many of the 22 CONSORT or STROBE items were complied with (each item was given equal weighting). This score was termed the quality score. Studies should satisfy at least five of 22 CONSORT or STROBE criteria to be eligible for inclusion. Our meta-analysis was conducted in accordance with the consensus recommendations of the Meta-analysis of Observational Studies in Epidemiology group (12).

Advance in Knowledge

- Daily routine chest radiography can be eliminated without increasing adverse outcomes in adult patients in intensive care units.

Implication for Patient Care

- Protocols promoting clinically indicated rather than daily routine chest radiography are recommended to reduce radiation exposure and healthcare costs.

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Abbreviations:
CI = confidence interval
ICU = intensive care unit
LOS = length of stay
OR = odds ratio
WMD = weighted mean difference

Author contributions:
Guarantor of integrity of entire study, Y.O.; study concepts/study design or data acquisition or data analysis/interpretation, Y.O., T.Z.; manuscript drafting or manuscript revision for important intellectual content, Y.O., T.Z.; approval of final version of submitted manuscript, Y.O., T.Z.; literature research, Y.O., T.Z.; clinical studies, Y.O., T.Z.; statistical analysis, Y.O., T.Z.; and manuscript editing, Y.O., T.Z.

Authors stated no financial relationship to disclose.

Data Analysis

ICU and hospital mortality and adverse event rates were dichotomous variables. ICU LOS and the duration of mechanical ventilation were continuous variables. The data analysis was performed by using meta-analysis software (RevMan, version 4.2, Cochrane Collaboration, Oxford, England; and STATA, version 10, Stata, College Station, Tex). The results were expressed as odds ratios (ORs) for dichotomous outcomes or weighted mean difference (WMD) for continuous outcomes, along with their 95% confidence intervals (CIs). A z test was performed to examine the overall effect. We tested heterogeneity between trials by using the I^2 statistic, with an I^2 of 50% or higher indicating significant heterogeneity (13). A random-effects model was used if significant heterogeneity was detected; otherwise, a fixed-effects model was used (14).

Univariate and multivariate regression meta-analyses were performed to identify a subgroup in which daily routine chest radiography was possibly beneficial. The variables included the expected and observed mortality rates, the proportion of medical or mechanically ventilated patients, and the type of study (randomized controlled trials vs observational studies) (Table 1). The expected mortality rates were calculated from the Simplified Acute Physiology Score II or Acute Physiology and Chronic Health Evaluation II scores reported in each study. Separate subgroup analyses were also performed by examining medical, surgical, or mechanically ventilated patients. Sensitivity analyses were also performed to assure the robustness of the results by excluding unmatched studies one by one or as a whole from the pooled analyses, and by using a random- or fixed-effects model, relative risks, and risk differences (15).

Results

Study Selection

The electronic database searches identified 128 citations. Initially, 23 studies were considered potentially relevant. After a more detailed review, an additional 14 papers were excluded for the lack of a comparison group (4–6,16–26) (Tables 2, 3; Table E1 [online]). The remaining nine studies were reviewed for duplicate publications. We found that the results of one study (27) had two separate subgroup analyses reported (28,29) (Schultz MJ, personal communication, Oct 19, 2008). The results from subgroup analyses were not included, except for the incidence of adverse events (28), because it was not reported in the whole-group analysis (27). A nonelectronic search identified one report that met our inclusion criteria (30). We included a total of eight studies in our analysis (2,3,9,27,30–33) (Fig 1).

Four studies reported major adverse events that included inadvertent extubations and reintubations (31), in-hospital complications requiring intervention (malpositioned tubes and catheters, mediastinal bleeding, instances of pneumothorax, and pleural effusions) (32), and readmissions to ICU (9,28).

Study Characteristics

Characteristics of included studies are summarized in Table 1 and Table E2 (online). Two studies were randomized controlled studies (2,3) and the rest were observational; study quality was variable. The quality score of the included studies ranged from 5 to 15 with a mean score of 9.6 (the maximum possible score was 22) (Table E2 [online]). The observational studies examined the effects of eliminating daily routine chest radiography before and after implementing

Table 1

Characteristics of Clinical Trials

Study	Study Design	No. of Patients	Duration (mo)	Type of patients	Ventilated Patients (%)	Expected Mortality (%)*	Observed Mortality (%)	Quality Score†
Brivet et al (30)	Observational before-after	1529	36	97% medical, 3% surgical	43	23	16	5
Clec'h et al (3)	Randomized controlled trial	165	6	75% medical, 25% surgical	100	60	33	15
Hendrikse et al (9)	Observational before-after	736	18	48% medical, 52% surgical	62	16	16	10
Krinsley et al (31)	Observational before-after	2564	35	69% medical, 31% surgical	36	26	20	8
Kripoval et al (2)	Randomized controlled trial	94	10	Medical	100	Not available	24	12
Kroner et al (27)	Observational before-after	1490	11	26% medical, 74% surgical	100	21	18	11
Leong et al (32)	Observational before-after	300	7	Surgical	100	Not available	3	9
Rao et al (33)	Observational	200	Not available	Surgical	100	Not available	Not available	7

* Based on Simplified Actue Physiology Score II or Acute Physiology and Chronic Health Evaluation Score II.

† Range, 0–22; 22 indicates the highest quality (10,11).

Figure 1

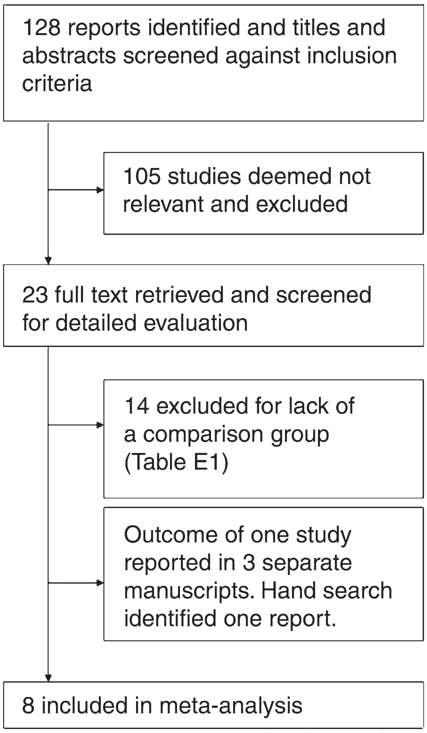

Figure 1: Flow of study selection.

Figure 2

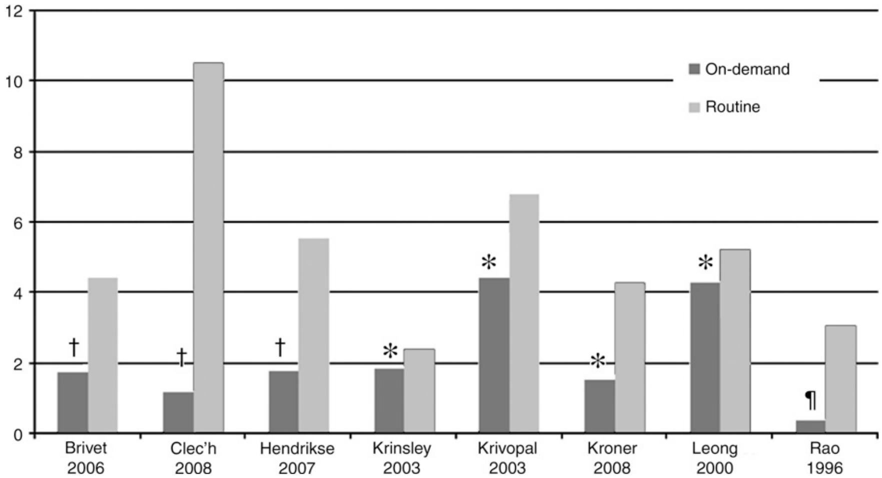

Figure 2: Mean number of chest radiographs per patient. † = *P* value not reported. * = < .05. ¶ = Significant reduction; *P* value not reported.

a protocol discouraging or banning the practice (27,30–32).

A total of 7078 ICU patents were included in this analysis in which 3429 underwent daily routine chest radiography (daily routine) and 3649 underwent only clinically indicated chest radiography (on-demand). The mean number of chest radiographs per patient ranged from 2.4 to 10.5 in the daily routine groups and from 0.4 to 4.4 in the on-demand groups (Fig 2), and was significantly lower in the on-demand groups compared with the daily routine groups (mean difference, 3.15; 95% CI: 0.88, 5.43; $P < .01$).

The mean age of included patients was 62.8 years (62.5 years for the routine group and 63.0 years for the on-demand group). Fifty-nine percent of the patients were medical (nonsurgical) and 61% of the patients were mechanically ventilated at the time of study entry. The mean observed mortality was 17%.

The baseline characteristics between daily routine and on-demand groups were similar, except in three observational studies (27,30,32). Older, more severely ill and frequently ventilated patients were included in the on-demand group in one study (30). The mortality rate from this study was adjusted for severity of illness. Another observational study (27) included more surgical patients in the on-demand group but other demographic characteristics were similar between the two groups including severity of illness scores. The third study included different types of surgical procedures and fewer emergent surgeries in the on-demand group (32). The effect of these unmatched studies on the pooled analysis was examined with sensitivity analyses by excluding these studies one by one and as a whole.

Mortality, LOS, and Adverse Events

A pooled analysis revealed that the elimination of daily routine chest radiography did not affect either hospital (OR, 1.02; 95% CI: 0.89, 1.17; P = .78) or ICU (OR, 0.92; 95% CI: 0.76, 1.11; P = .4) mortality. There was no evidence of statistical heterogeneity among the included trials (I^2 = 0%). There was no significant difference in the hospital mortality between the on-demand and daily routine groups when the randomized controlled trials (OR, 0.97; 95% CI: 0.57, 1.64; P = .90) or observational studies (OR, 1.02; 95% CI: 0.89, 1.18; P = .75) were separately analyzed, which was also true for the ICU mortality (OR, 1.06; 95% CI: 0.55, 2.02; P = .87 for randomized controlled trials and OR, 0.91; 95% CI: 0.75, 1.11; P = .35 for observational studies) (Figs 3, 4).

The study results revealed no significant difference in ICU LOS (random WMD = 0.19 days; 95% CI: −0.13, 0.51; P = .25), hospital LOS (fixed WMD = −0.29 days; 95% CI: −0.71, 0.13; P = .18), and ventilator days (fixed WMD = 0.33 days; 95% CI: −0.12, 0.78; P = .15) between the on-demand and daily routine groups (Figs 5–7). The results were unchanged when the randomized controlled trials (−1.03 days, 95% CI: −4.35, 2.30; P = .55 for ICU LOS; 1.04 days, 95% CI: −2.5, 1.61; P = .23 for hospital LOS; and −0.77 days, 95% CI: −2.36, 0.83; P = .34 for ventilator days) or observational studies (0.21 days; 95% CI: −0.12, 0.53; P = .21 for ICU LOS; −0.27 days; 95% CI: −0.69, 0.16; P = .22 for hospital LOS; and 0.43 days, 95% CI: −0.04, 0.90; P = .07 for ventilator days) were separately analyzed. The incidence of adverse events was also similar between the on-demand and daily routine groups (OR, 0.93; 95% CI: 0.57, 1.53; P = .78; Fig 8).

Subgroup and Sensitivity Analyses

Univariate and multivariate regression meta-analyses failed to identify any subgroup in which daily routine chest radiography was possibly beneficial.

Figure 3

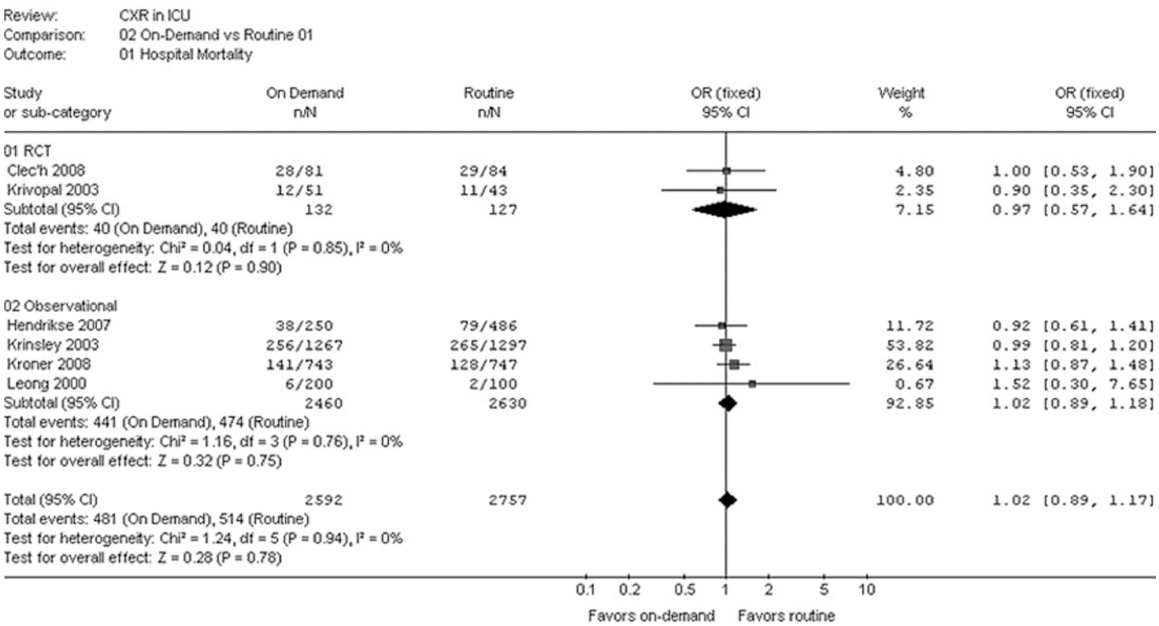

Figure 3: Forest plot for effect of daily routine chest radiography on hospital mortality. *CXR* = chest radiography, *RCT* = randomized controlled trial.

Figure 4

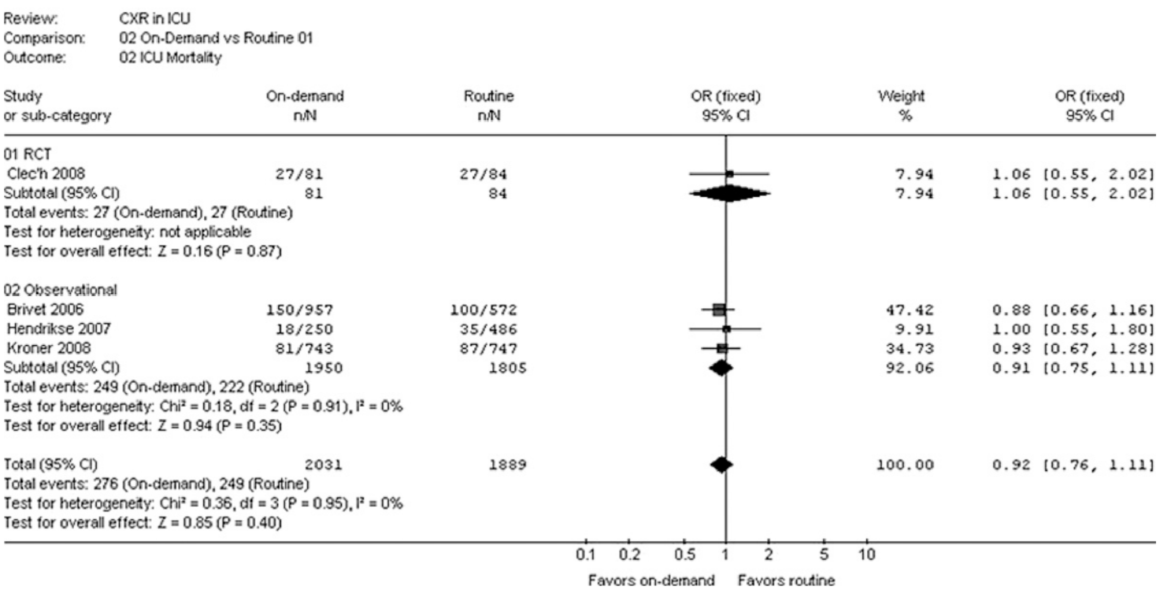

Figure 4: Forest plot for effect of daily routine chest radiography on ICU mortality. *CXR* = chest radiography, *RCT* = randomized controlled trial.

None of the variables, including the expected and observed mortality rates, the proportion of medical or mechanically ventilated patients, and the type of study (randomized controlled trials vs observational studies) significantly affected the study results (data are not shown as a result of nonsignificance).

Subgroup analyses examining medical, surgical, or mechanically ventilated patients did not show significant differences on any outcome between the daily routine and on-demand groups (Table 4). Excluding the unmatched studies one by one or as a whole from the pooled analyses did not affect the results. Sensitivity analyses performed by using a random- or fixed-effects model, relative

Figure 5

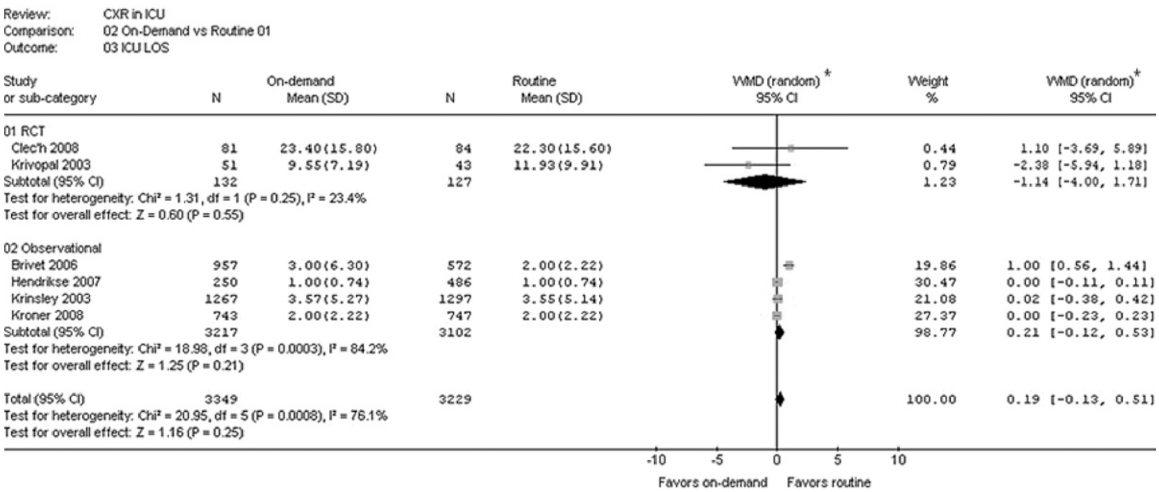

Figure 5: Forest plot for effect of daily routine chest radiography on ICU LOS. *CXR* = chest radiography, *RCT* = randomized controlled trial, *SD* = standard deviation.

Figure 6

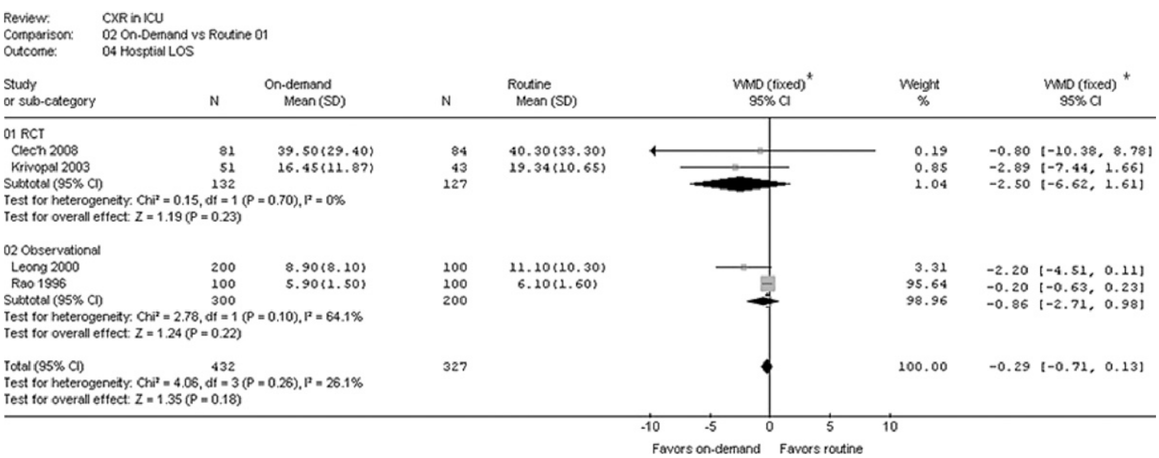

Figure 6: Forest plot for effect of daily routine chest radiography on hospital LOS. *CXR* = chest radiography, *RCT* = randomized controlled trial, *SD* = standard deviation.

risks, and risk differences did not affect the results either.

Discussion

Obtaining a daily routine chest radiograph for every ICU patient remains a common practice despite the accumulating evidence suggesting that this may not be necessary (2,6). This practice, as well as the recommendations of the American College of Radiology (1) are based on studies from the 1980s and early 1990s that reported the high incidence of new or unexpected findings seen on daily routine chest radiographs (16–19,21,22). We reviewed literature advocating daily routine chest radiography in ICUs. All studies were observational without a comparison group and did not report objective data on patient outcomes, such as length of mechanical ventilation, ICU stay, and mortality. The efficacy of daily routine chest radiography, as reported in these studies, was probably overestimated because of inadequate study design and other reasons, as summarized in Table 2.

More recent studies reported a lower incidence of unexpected radiographic abnormalities that led to a change in treatment (4,6). One study reported that most of the radiographic abnormalities were clinically anticipated and only two (1%) substantial changes in radiographic findings were missed at clinical examination (23).

The difference in opinion on the utility of daily routine chest radiography and the discrepancy of efficacy data are probably a result of differences in patient population, enrollment criteria,

Figure 7

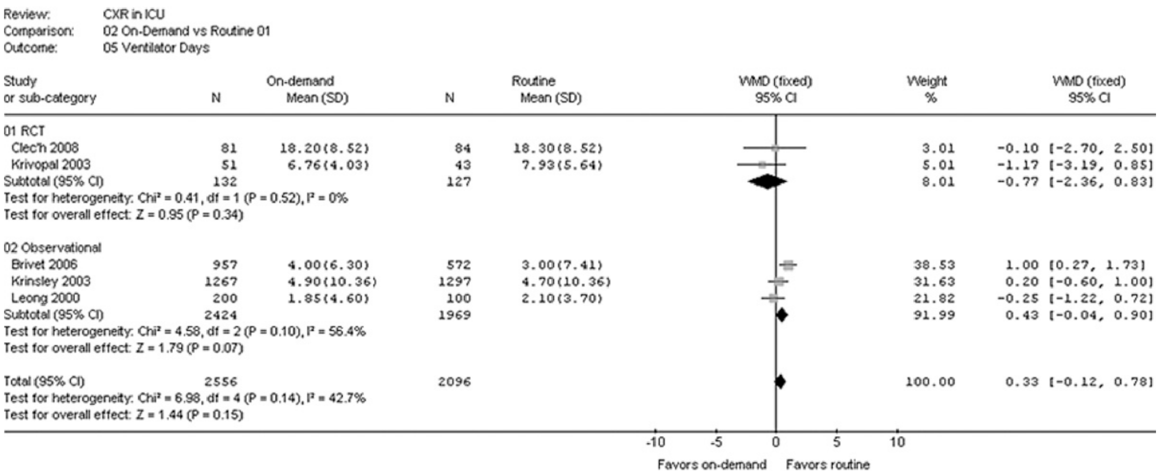

Figure 7: Forest plot for the effect of daily routine chest radiography on ventilator days. *CXR* = chest radiography, *RCT* = randomized controlled trial, *SD* = standard deviation.

Figure 8

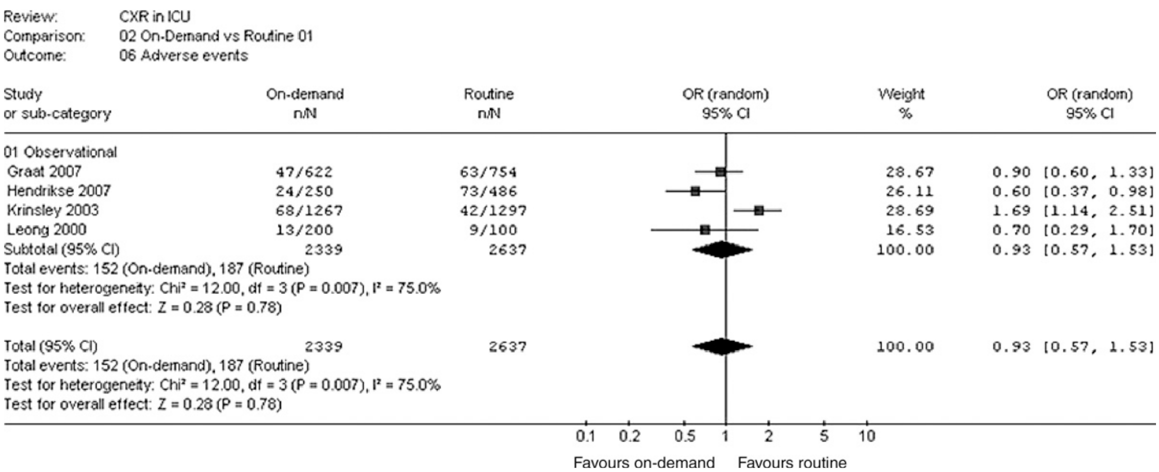

Figure 8: Forest plot for effect of daily routine chest radiography on adverse events. *CXR* = chest radiography, *RCT* = randomized controlled trial, *SD* = standard deviation.

degree of reliance on radiographic findings, and various definitions of efficacy (unexpected findings vs new findings vs findings that led to treatment change) (Tables 2, 3).

The incidence of malpositioned medical devices in those patients undergoing daily routine chest radiography also varied. One study reported 13% of all radiographs prompted an adjustment of malpositioned medical devices (26), while another study reported this only in 1.3% of cases (4). The clinical judgment regarding a medical device that needs to be repositioned can often be subjective. Most of the reported abnormalities in earlier studies could have been clinically insignificant given no significant difference in clinical outcomes in our meta-analysis. It is possible that the incidence of malpositioned medical devices was overestimated in the older studies.

Silverstein et al (4) reported an extremely low yield of clinically significant device malposition on routine chest radiographs (of 1028 [1.3%] medical devices) and suggested that ICU nurses could monitor the position of medical devices at bedside by recording its position each shift instead of obtaining daily routine chest radiographs.

Our study results are in accordance with a recent French survey that found that 75% (of 82) of ICU specialists did not indicate that daily routine chest radiography was needed in an intubated patient (34). In Germany, government regulations require each radiograph be ordered with a documented clinical indication, which makes daily routine chest radiographs illegal (35). Performing chest radiography for a specific indication rather than on a routine basis may reduce workload, radiation exposure to

Table 2

Studies Advocating Daily Routine Chest Radiography

Study	No. of Radiographs	Main Result	Conclusion	Comment
Greenbaum (16)	200	Unexpected new findings on 27% of usable radiographs.	Routine chest radiography was judged as valuable in helping identify abnormalities in critically ill patients.	37% of radiographs were excluded for various reasons, which may have overestimated efficacy.
Henschke (17)	1132	New findings or changes affecting treatment were present in 65% of radiographs.	The use of bedside radiography appeared to be appropriate.	Admission, postprocedure, and clinically indicated radiographs were not excluded.
Janower (18)	183	37% of radiographs showed unexpected new finding.	Results tend to justify ICU physicians' perceived need for daily radiography.	Influence of unexpected findings on treatment was not reported.
Bekemyer (19)	1354	45% of routine radiographs showed unexpected or increased findings; 38.7% prompted treatment change.	Routine morning radiographs frequently show unexpected abnormalities, many of which prompt changes in diagnosis or treatment.	No data reported regarding routine radiographs altering patient outcomes; no comparison made with clinically indicated radiographs.
Horst (21)	411	30% (of 138) of unexpected findings were considered potentially life threatening.	Routine morning radiography is recommended in critically ill surgical patients.	Radiographs obtained after surgery/ procedure and those clinically indicated were not excluded.
Hall (22)	538	New major findings were discovered only at radiography in 13 patients.	Routine chest radiographs have substantial effect on treatment of mechanically ventilated patients.	New major findings not anticipated at bedside were discovered only on 3.4% of all radiographs.
Brainsky (24)	221	8% (of 221) of routine radiographs prompted action; experts predicted each action would have averted a mean of 2.1 ICU days.	The policy of obtaining routine chest radiographs in medical ICU is effective.	The estimated length of potentially averted ICU stay is subjective.
Marik (25)	471	37% of chest radiographs prompted change in therapy.	Routine daily radiography may be justified in critically ill medical patients.	No data were presented on unexpected findings; no comparison was made with clinically indicated radiographs.

Table 3

Studies Advocating Selective Use of Chest Radiography

Study	No. of Radiographs	Main Result	Conclusion	Comment
Strain (20)	507	Only 14% of routine radiographs led to a treatment change.	Routine radiographs are useful only in pulmonary and complicated cardiac patients.	A single-center study with a relatively small number of patients ($n = 94$); external validation is necessary.
Silverstein (4)	525	Only 16 (3%) radiographs had any potential clinical effect.	Routine radiography should be abandoned; radiography need should be based on clinical necessity.	The study included patients admitted to surgical ICU and did not identify more critically ill patients.
Fong (5)	1003	17% of routine radiographs showed clinically important findings.	Multivariate analysis suggested routine radiography was justified only with pulmonary artery catheters.	The proportion of routine radiographs that revealed clinically important findings in patients without a pulmonary artery catheter was not described.
Bhagwanjee (23)	164	Only two (1%) substantial chest radiographic changes were missed at clinical examination.	Clinical examination can effectively help predict the need for chest radiography.	The patient population, young and primarily admitted following trauma, could have contributed to the low yield.
Chahine-Malus (26)	645	19.7% of routine radiographs led to treatment change; the majority of which involved repositioning medical devices.	Daily chest radiography may not be necessary for all patients.	The proportion of routine radiographs prompting treatment change appears relatively high; patients that could avoid daily radiography were not specified.
Graat (6)	2457	Only 2.2% of routine radiographs led to treatment change.	Daily routine chest radiography should be abandoned.	Rare but potentially serious consequences of a missed finding were not discussed.

Table 4

Sensitivity Analysis

Outcome and Patient Type	On-demand vs Routine Radiography	*P* Value
Hospital mortality	OR (fixed)	
Medical	0.97 [0.57, 1.64]	.9
Surgical	1.08 [0.86, 1.34]	.51
Ventilator	1.11 [0.88, 1.40]	.4
ICU mortality	OR (fixed)	
Medical	0.90 [0.70, 1.17]	.43
Surgical	0.93 [0.67, 1.28]	.65
Ventilator	0.91 [0.75, 1.11]	.9
ICU LOS days	WMD (random)	
Medical	0.36 [−0.57, 1.28]	.45
Surgical	0.00 [−0.23, 0.23]	>.99
Ventilator	0.33 [−0.59, 1.26]	.48
Ventilator days	WMD (fixed)	
Medical	0.50 [−0.02, 1.01]	.06
Surgical	−0.25 [−1.22, 0.72]	.61
Ventilator	0.11 [−0.89, 1.10]	.84
Adverse events	OR (random)	
Medical	1.02 [0.37, 2.82]	.97
Surgical	0.86 [0.60, 1.23]	.42
Ventilator	0.86 [0.60, 1.23]	.42

Note.—Numbers in square brackets are 95% CIs.

patients and healthcare personnel, and healthcare costs (5,30).

Researchers have tried identifying subpopulations that would benefit from daily routine chest radiography. One study (20) concluded that daily routine chest radiography was useful for pulmonary and complicated cardiac patients. A multivariate analysis in another study (5) suggested that daily routine chest radiography was justified in patients with pulmonary artery catheters. However, our regression analyses failed to identify any subpopulation that would benefit from daily routine chest radiography. The possible explanation for this includes but is not limited to the following: *(a)* There is no subgroup that would benefit from daily routine chest radiography, *(b)* the efficacy of daily routine chest radiography on clinical outcomes may be too marginal to detect, *(c)* there is not enough data to identify the subgroup, or *(d)* a physician's intuition for determining the need for daily routine chest radiographs cannot be captured with current clinical classifications.

Our study had several limitations. First, it included both randomized control and observation studies. Although a meta-analysis including only randomized control studies is preferable, a systematic review including randomized and observational studies provides a tool for synthesizing clinical data when there is a paucity of randomized controlled studies. In addition, Concato et al (36) found that the results were remarkably similar when meta-analyses of randomized control trials were compared with those of observational studies that assessed the same intervention. We found no difference in the results when randomized control trials and observation studies were analyzed separately or combined.

Second, the baseline demographic characteristics were not similar in the three observational studies (27,30,32) that were included in the analysis. The mortality rates were adjusted whenever possible but adjustments for other outcomes were not possible owing to a lack of data. However, sensitivity analyses excluding the unmatched studies one by one and as a whole did not affect the results of any outcomes and assured the robustness of the results. Third, our study results may not be applicable to patients with a mortality rate higher than those of the patients studied in our analysis. The mean observed mortality rates among included studies ranged from 3% to 33%. It may not be feasible to perform a randomized control study with a higher severity of illness because treating physicians may not feel comfortable under these circumstances or feel that it is unethical. Given the limitation of the analysis, it is possible that there is a subgroup of the ICU patients that would benefit from daily routine chest radiography. However, identifying the subgroups may not be possible because of the limited feasibility of such clinical studies and the complexity of ICU patients. Fourth, one study from the meta-analysis included substantially more patients than the others (31). This might have created bias in the results; however, a sensitivity analysis excluding that study did not affect the results of any outcomes and assured the robustness of the results.

In summary, our systematic analysis demonstrates that the elimination of daily routine chest radiography did not adversely affect hard outcomes, such as hospital or ICU mortality, hospital or ICU length of stay, and ventilator days. Therefore, we assert that daily routine chest radiography can potentially be safely eliminated in most ICU patients. Further studies are necessary to identify the specific patient population that would benefit from undergoing daily routine chest radiography and at what time during the course of a patient's care the value of daily radiography diminishes. Meanwhile, protocols that promote undergoing clinically indicated rather than daily routine chest radiography are recommended to reduce unnecessary radiation exposures and healthcare costs.

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