Reduction of Chest Drain Overuse Through Implementation of a Pleural Drainage Order Set

Pattraporn Tajarernmuang, MD; David Valenti, MD; Anne V. Gonzalez, MD, MSc; Giovanni Artho, MD; Mary Tsatoumas, MD; Stéphane Beaudoin, MD

Background and Objectives: Small chest drains are used in many centers as the default drainage strategy for various pleural effusions. This can lead to drain overuse, which may be harmful. This study aimed to reduce chest drain overuse. **Methods:** We studied consecutive pleural procedures performed in the radiology department before (August 1, 2015, to July 31, 2016) and after intervention (September 1, 2019, to January 31, 2020). Chest drains were deemed indicated or not based on criteria established by a local interdisciplinary work group. The intervention consisted of a pleural drainage order set embedded in electronic medical records. It included indications for chest drain insertion, prespecified drain sizes for each indication, fluid analyses, and postprocedure radiography orders. Overall chest drain use and proportion of nonindicated drains were the outcomes of interest. **Results:** We reviewed a total of 288 procedures (pre-intervention) and 155 procedures (post-intervention) (thoracentesis and drains). Order-set implementation led to a reduction in drain use (86.5% vs 54.8% of all procedures, $P < .001$) and reduction in drain insertions in the absence of an indication (from 45.4% to 29.4% of drains, $P = .01$). The need for repeat procedures did not increase after order-set implementation (22.0% pre vs 17.7% post, $P = .40$). Complication rates and length of hospital stay did not differ significantly after the intervention. More pleural infections were treated with drain sizes of 12Fr and greater (31 vs 70%, $P < .001$) after order-set deployment, and direct procedural costs were reduced by 27 CAN$ per procedure. **Conclusion:** Implementation of a pleural drainage order-set reduced chest drain use, improved procedure selection according to clinical needs, and reduced direct procedural costs. In institutions where small chest drains are used as the default drainage strategy for pleural effusions, this order set can reduce chest drain overuse.

Key words: chest tubes, pleural drainage, quality improvement

Chest drain insertion is performed in various pleural diseases. Over the last decade, there has been a paradigm shift toward the use of small-bore catheters (16Fr or less). They have been used for the treatment of pneumothorax, pleural infection, pleurodesis, and pleural effusion drainage from various etiologies.[1,2] Despite their small size, potential complications related to their use include pain, organ puncture, intrapleural infection, iatrogenic pneumothorax, drain dislodgement, and blockage.[1,3-5]

Publications supporting the routine use of small drains for managing pleural effusions did not evaluate whether they added therapeutic value compared with thoracentesis, nor their incremental costs, harms, and impact on patient experience.[1-3,6-8] The British Thoracic Society guidelines recommend chest drain insertion under specific conditions, such as pneumothorax and pleural infection. However, chest drain insertion for noninfected effusions of undetermined etiology is discouraged.[9] In the United Kingdom, reports of severe complications from chest drain placement led to national audits and the development of initiatives to reduce their use and increase their safety.[5]

Historically, in our center, most nontrauma in-hospital pleural drainage procedures were performed in the radiology department, and the default procedure was a small drain insertion. A practice audit showed that such a strategy led to almost half of the drains being inserted without a specific indication and with significant associated harms.[10] To address chest drain overuse, we developed a pleural drainage policy operationalized through an order set integrated into our electronic medical records (EMRs).

__Author Affiliations:__ Respiratory Division, Department of Medicine (Drs Tajarernmuang, Gonzalez, and Beaudoin) and Department of Radiology (Drs Valenti, Artho, and Tsatoumas), McGill University Health Centre, Montreal, Quebec, Canada; and Division of Pulmonary, Critical Care, and Allergy, Department of Internal Medicine, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand (Dr Tajarernmuang).

__Correspondence:__ Stéphane Beaudoin, MD, Respiratory Division, Department of Medicine, McGill University Health Centre, 1001 Bd Décarie, Montréal, QC H4A 3J1, Canada (stephane.beaudoin@mcgill.ca).

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MATERIALS AND METHODS

Study design

This was a pre- and post-intervention comparative study using retrospective assessments for each period. Consecutive adult patients who underwent a pleural procedure in the radiology department of our institution (identified through the radiology information system database) from August 1, 2015, to July 31, 2016 (pre-intervention), and from September 1, 2019, to January 31, 2020 (post-intervention), were included. This project was approved by our institutional research ethics board (study number 2017-3145).

Intervention

At study inception, an interdisciplinary work group comprising a respirologist, a radiologist, an internist, and a thoracic surgeon agreed upon a list of indications for chest drains, namely (1) symptomatic primary spontaneous pneumothorax, (2) symptomatic or large secondary or iatrogenic pneumothorax, (3) trauma-related pneumothorax, (4) confirmed or highly suspected complicated parapneumonic effusion or empyema, (5) confirmed pleural infection of other origin, (6) massive pleural effusion (occupying more than 2/3 of hemithorax with severe dyspnea or hypoxemia unlikely to resolve with thoracentesis), (7) effusions in patients on mechanical ventilation, (8) confirmed hemothorax, and (9) other effusion requiring a drain as per respirology/thoracic surgery. Pre-intervention data revealed that 87% of all radiology pleural procedures were chest drains, 45% were not indicated, and the drain size was often not adapted to clinical needs (only 31% of infected effusions were treated with drains ≥12Fr).

In addition, some chest drainage practices were suboptimal (infrequent use of a closed pleural drainage system upfront, use of locking catheters, delays in postprocedure imagery, and inadequate fluid analyses). The previously mentioned work group developed a pleural drainage policy (full policy in the Supplemental Digital Content 1, available at: http://links.lww.com/QMH/A110) to address the issues identified. In brief, the use of chest drains was limited to the indications mentioned previously, and a drain size was recommended for each. In the absence of drain insertion criteria, diagnostic and/or therapeutic thoracentesis was the default procedure (limited to 1.5 L, using vacuum bottles). In addition, fluid analyses had to be sent directly from the radiology department, and a post-intervention radiography (if necessary) was to be performed before returning to the ward.

The policy was operationalized through a specifically designed pleural drainage order set in our EMRs (see Supplemental Digital Content 2, available at: http://links.lww.com/QMH/A111). The order set became the standard method to request a pleural procedure in radiology. In this order set, physicians must indicate the presence of a pleural drain indication using a checklist. The procedure to be performed (ie, drain vs thoracentesis) is determined by the presence or absence of a drain indication. Fluid analyses and postprocedure radiographies are ordered automatically, with the option of removing or adding tests.

Before implementation in January 2019, radiologists and radiology technicians received in-person training on this policy. Attendings and residents from all specialties received an email describing the order set and relevant parts of the policy, and lectures were given at medical grand rounds to medical residents and staff. Based on user feedback and interim audits, an updated version of the order set was launched in August 2019. We hypothesized that implementation of the order set would reduce overall chest drain use and reduce drain insertions in the absence of recommended indications.

Data collection and outcomes

Demographic, clinical, radiological, and procedural data were extracted from the EMRs. The primary outcomes were the change in the proportion of chest drains over all pleural procedures between the pre- and post-intervention periods, and the change in the proportion of drains inserted without an indication. Predefined secondary outcomes included complications, proportion of repeat procedures in the same patient, rate of pleural infection managed with drain size of 12Fr and greater, hospital length of stay, proportion of examinations with inadequate fluid tests, and delays in postprocedure imagery.

Sample size

With an estimated reduction of nonindicated drains from 45% to approximately 20% (based on an interim audit in June 2019), 53 procedures were required to achieve a power of 85%, with an α error of 5% (with a fixed pre-intervention group of 288 procedures). To account for the variability in the main outcomes over time and to increase our ability to detect differences in secondary outcomes, 155 post-intervention procedures were included.

Statistical analysis

Continuous variables were compared using the 2-tailed Student t test for normally distributed data or the Mann-Whitney test for nonparametric data, whereas categorical variables were compared using the χ^2 or Fisher exact test (SAS software version 9.4). Statistical significance was set at P value of less than .05.

RESULTS

A total of 288 procedures (205 patients) were included in the pre-intervention period and 155 (113 patients) in the post-intervention period. The baseline characteristics of the 2 groups are shown in Table 1. Almost all patients were hospitalized. The post-intervention period included more malignant effusions and pneumothorax but fewer cases of infection. More procedures were performed by interventional radiologists during the post-intervention period.

After the implementation of the pleural drainage policy and order set, there was a significant reduction in

Table 1. Baseline Characteristics of Patients in the Pre- and Post-Intervention Groups

	Pre-Intervention 288 Procedures 205 Patients N (%)	Post-Intervention 155 Procedures 113 Patients N (%)
Age, mean (SD), y	67.0 (15.1)	68.7 (16.0)
Female proportion	84 (41.0)	41 (36.3)
Inpatient procedure	270 (93.8)	151 (97.4)
Trainee involvement	236 (81.9)	102 (65.8)
Admission site for inpatients		
Medical ward	95 (35.2)	54 (35.8)
Surgical ward	113 (41.9)	45 (29.8)
ICU/CCU	33 (12.2)	33 (21.9)
Emergency department	16 (5.9)	16 (10.6)
Other[a]	13 (4.8)	3 (2.0)
Diagnosis		
Infection	100 (34.7)	30 (19.4)
Tuberculosis	0	2 (1.3)
Malignancy	57 (19.8)	41 (26.5)
Post–cardiac surgery	9 (3.1)	11 (7.1)
Transudates	58 (20.1)	40 (25.8)
Hemothorax	14 (4.9)	2 (1.3)
Pneumothorax	5 (1.7)	15 (9.7)
Other causes	43 (14.9)	14 (9.0)
Ultrasound guidance[b]	278 (96.5)	141 (91.0)
Operator		
Ultrasound radiologist	278 (96.5)	141 (91.0)
Interventional radiologist	10 (3.5)	14 (9.0)
Effusion side		
Right	164 (56.9)	98 (63.2)
Left	124 (43.1)	57 (36.8)
Effusion size on chest radiography		
<1/3 hemithorax	139 (48.9)	53 (38.7)
<2/3 hemithorax	120 (42.2)	72 (52.6)
>2/3 hemithorax	25 (8.8)	12 (8.8)
Amount drained[c], L; median (Q1, Q3)	1.2 (0.6, 1.9)	1.4 (0.8, 2.5)

Abbreviations: CCU, critical care unit; ICU, intensive care unit.
[a]Other sites included palliative care ward, geriatric ward, and short stay unit.
[b]Procedures done without ultrasound guidance were done with computed tomography or fluoroscopy guidance.
[c]Restricted to chest drain insertion procedure due to missing data with thoracenteses in the pre-intervention period.

chest drain use (86.5% vs 54.8% of all procedures, $P < .001$; Table 2). Nonindicated drains represented 39.2% of the total procedures pre-intervention and only 16.1% post-intervention ($P < .001$) (Figure). Data from the 2 months preceding the implementation of the order set (N = 39 procedures) show that there was no downward trend in nonindicated drains before implementation (Figure). When looking strictly at drain placements, 45.4% were not indicated pre-intervention and 29.4% post-intervention ($P = .01$). Factors leading to drain use without indication in the post-intervention period are shown in Table 3. In most cases, physicians ordering the procedure misused the order set by indicating the presence of a drain indication (most commonly massive effusion + hypoxemia) that was not present.

The probability of undergoing a repeat procedure was slightly reduced in the post-intervention period (22.0% vs 17.7% for the second procedure and 6.5% vs 4.0% for the third procedure), but this was not statistically significant (Table 2). Similarly, the length of hospital stay did not change significantly between the 2 periods studied. The use of drain sizes of 12Fr and greater in cases of pleural infection increased significantly (30.9% vs 69.6%, $P = .001$). The use of locking catheters decreased markedly and the use of closed pleural drainage systems after drain insertion increased significantly in the post-intervention period (Table 2). Fluid analyses were more often adequate for assessing Light's criteria in the post-intervention period. The delay to postdrain insertion radiography diminished from a median of 19.0 hours to 1.4 hours after order-set implementation ($P < .001$). There was no statistically significant difference in the rates of complications before and after order-set implementation (Table 4). Similarly, the observed reduction in postprocedural narcotic prescriptions was not statistically significant. In terms of direct procedural costs, based on an annual volume of 300 pleural procedures performed in radiology, the drainage policy and order set reduced direct costs by an estimated 8000 CAN$ per year or 26.70 CAN$ per procedure (including drains, drain stabilization device, drain adaptor, and closed pleural drainage system). And billing fees could have been reduced by 9000 CAN$ per year (or 30 CAN$ per procedure).

DISCUSSION

The implementation of a pleural drainage policy using an EMR-based order set led to a marked reduction in drain use and significantly reduced the number of nonindicated drains. This was accompanied by an improvement in procedure selection according to clinical needs (evidenced by reduced use of very small drains in pleural infections) and a small but significant cost reduction.

Small-bore drains are widely used to manage pleural effusions of various etiologies because of their ease

Table 2. **Chest Drain Use and Periprocedural Care**

Categories	N	Pre-Intervention N (%)	N	Post-Intervention N (%)	*P*
Type of procedure	288		155		<.001
Chest drain insertion		249 (86.5)		85 (54.8)	
Thoracentesis		39 (13.5)		70 (45.2)	
Proportion of drains inserted without an indication (over number of drains)	249	113 (45.4)	85	25 (29.4)	.01
Proportion of drains without an indication (over total procedures)	288	113 (39.2)	155	25 (16.1)	<.001
Indications for chest drains with an indication	249		85		
• Pleural infection		81 (32.5)		23 (27.1)	
• Massive effusion + distress/hypoxemia		4 (1.6)		6 (7.1)	
• Ventilated patients in ICU/CCU		34 (13.7)		14 (16.5)	
• Hemothorax		12 (4.8)		2 (2.4)	
• Pneumothorax		5 (2.0)		15 (17.6)	
Use of locking catheters	248	245 (98.8)	85	2 (2.4)	<.001
Use of a closed pleural drainage system at insertion	249	61 (24.5)	84	80 (95.2)	<.001
Use of drain ≥12Fr for pleural infection	81	25 (30.9)	23	16 (69.6)	<.001
Fluid profile sufficient for Light's criteria evaluation[a]	196	139 (71.9)	116	95 (81.9)	.02
Postprocedure management					
Delay from procedure to follow-up chest imaging in hours; median (Q1, Q3)[b]		19.0 (5.0, 24.0)		1.4 (1.0, 2.5)	<.001
Duration of chest drainage in days; median (Q1, Q3)		3.5 (2.0, 6.0)		3.0 (2.0, 6.0)	.331
Second procedure required[c]	200	44 (22.0)	124	22 (17.7)	.355
Third procedure required[c]	200	13 (6.5)	124	5 (4.0)	.346
Length of hospital stay[d]; median (Q1, Q3)	174	20.5 (9.0, 47.0)	114	15.5 (7.0, 35.0)	.226

Abbreviations: CCU, critical care unit; ICU, intensive care unit.
[a]Restricted to first procedure done during an admission and excluding pneumothorax.
[b]Restricted to chest drain insertion.
[c]Denominator is the number of initial procedures during a hospital stay.
[d]Calculated on a per-admission basis.

Table 3. **Factors Leading to Drain Insertion Without Indication After Order-Set Implementation**

	25 Drains Without Indication Post-Intervention N (%)
Order set not used	2 (8.0)
Order set misused by prescriber[a]	22 (88.0)
Order set misused by proceduralist[b]	1 (4.0)
Order set used, drain left in for complication[c]	1 (4.0)

[a]The prescriber indicated a chest drain indication on the order set in the absence of one. Massive effusion + distress (12 cases), drain required as per thoracic surgery (3 cases), and infection (3 cases) were the most common criteria inappropriately chosen.
[b]Proceduralist inserted a drain despite the absence of indication on the order set.
[c]The patient became unwell with chest pain and dizziness after 1 L was removed, and a drain was left in place to evacuate the remaining amount later on.

of insertion. However, their lack of added therapeutic value, their additional complications, and additional costs compared with thoracentesis have not been properly addressed in the series supporting their routine use to manage effusions.[1-3,6-8] Although order-set implementation has been shown to reduce resource use in a variety of settings,[11,12] its impact on pleural procedures has not been described before.

The very high degree of order-set use in this study occurred because it became the easiest way to request pleural procedures in radiology and significantly improved the workflow for clinicians (procedure, fluid analyses, and post-intervention radiography requested through a single EMR order). There were no unintended consequences of the order-set implementation. Importantly, reduction in chest drain use did not lead to more repeat procedures, meaning that patients who required a drain were not initially managed with thoracentesis instead.

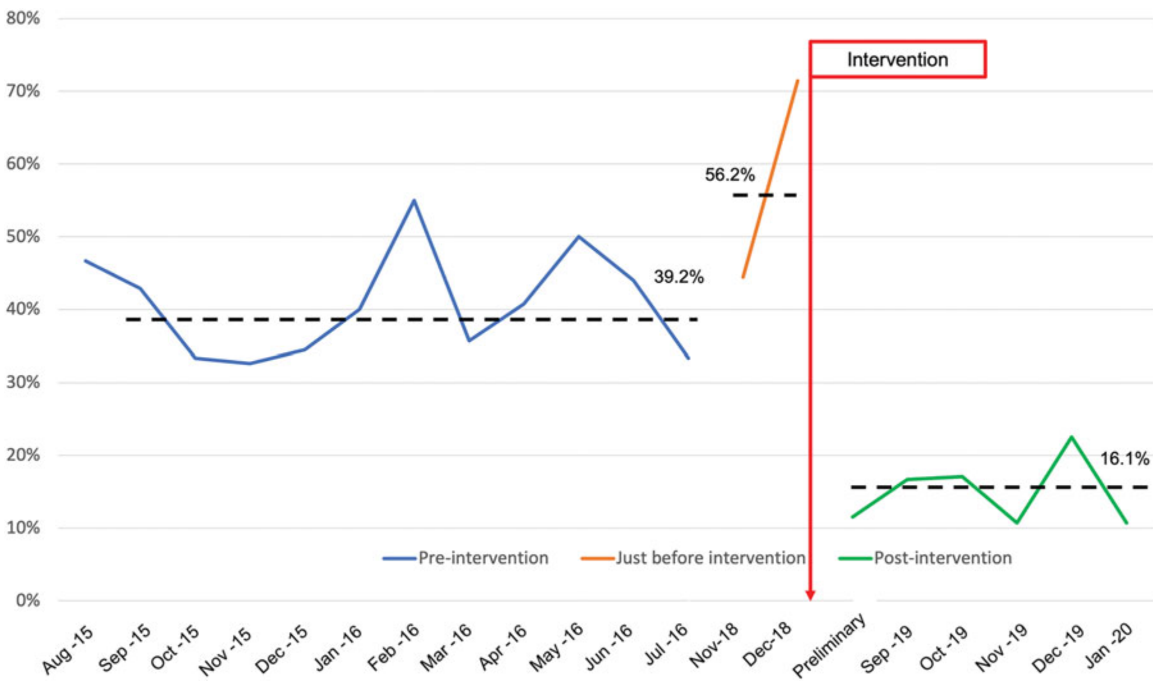

Figure. Ratio of nonindicated drains to total procedures pre-intervention compared with post-intervention.

Table 4. Complications Related to Pleural Procedures

Complications	Pre-Intervention 288 Procedures, 205 Patients N (%)	Post-Intervention 155 Procedures, 113 Patients N (%)	*P*
Major complications			
Bleeding	2 (0.7)	1 (0.6)	1.000
Organ puncture	3 (1.0)	1 (0.6)	1.000
Pneumothorax	58 (20.1)	23 (14.8)	.198
Pneumothorax requiring intervention[a]	6 (2.1)	2 (1.3)	.719
Infection (skin/intrapleural)	0	0	. . .
Total major complications[b]	62 (21.6)	25 (16.1)	.210
Minor complications			
Subcutaneous emphysema	9 (3.1)	3 (1.9)	.553
Drain blockage	18 (6.3)	3 (1.9)	.058
Drain dislodgement	7 (2.4)	7 (4.5)	.262
New narcotic required after procedure, on a per-patient basis	49 (24.1)	20 (17.7)	.203
New narcotics required, for chest drain patients	46 (27.1)	16 (26.2)	
New narcotics required, for thoracentesis patients	3 (9.1)	4 (7.7)	
Other complications[c]	3 (1.0)	0	.555
In-hospital death[d]	41 (14.2)	31 (20.0)	.117

[a]Intervention defined as use of suction, increased oxygen therapy, upsizing the chest drain, and need for a second drain.
[b]The denominator varied (for the pre-intervention group, from 286 to 288 procedures) since some complications could not be ascertained because of insufficient data in some cases (patients who came to our center just for a procedure, for instance).
[c]One pneumoperitoneum; 2 chest drains were placed in the chest wall.
[d]No procedure-related death.

Although a prospective cost analysis was beyond the scope of this study, the reduction in direct procedural costs remained significant (8000 CAN$/year). This corroborates a recent analysis of a US national registry showing an association between increased costs and length of stay with the use of chest drain instead of thoracentesis for hospitalized patients with malignant effusions.[13]

However, the pleural drainage policy and order set failed to completely eliminate the nonindicated chest drains. Despite repeated education efforts through various channels, some clinicians misused the order set by selecting a drain indication when none was present. Although the order set became the standard for ordering radiology-based pleural procedures, it could be bypassed through alternate paths in the EMR. Unfortunately, objective data on the reasons leading to order-set bypass or misuse are lacking. We hypothesize that contributing factors include some physicians' unfamiliarity with the order set and others' decision to request a chest drain despite the absence of an indication due to the deeply ingrained culture of their use. Notably, the intervention in this study did not include mandatory respirology or pleural service consultation before the procedure was requested. Whether this would have improved the outcomes remains unclear. A significant proportion of complicated pleural infections is still treated with very small drains despite our intervention, which is another shortcoming. Although an ad hoc analysis of the Multicenter Intrapleural Sepsis Trial 1 (MIST1) showed no difference in outcomes between small (<15Fr) and large (≥15Fr) catheter subgroups, few patients were treated with drains smaller than 10Fr,[14] which are prone to occlusion. The pleural drainage policy and order set also failed to reduce complications in a statistically significant fashion, partly because of the limited power to address this outcome. The most common complication remains asymptomatic small pneumothorax, and this is postulated to be related to technical factors (lack of needle hub capping during sampling or connection to drainage systems, for instance) rather than true lung injury, as evidenced by the very low rate of pneumothorax requiring intervention. Initiatives to address these shortcomings are underway.

It may also be argued that certain drain indications (massive effusion with hypoxemia/distress and effusions in ventilated patients) can be managed with thoracentesis. Because of the major practice shift with the order-set implementation and the unfamiliarity of radiologists with large-volume thoracentesis, therapeutic thoracentesis was limited to 1.5 L. Although the amount that can be safely removed by thoracentesis is a matter of debate (the British Thoracic Society guidelines recommended a 1.5-L limit),[9] in large series in which no limit was imposed, re-expansion edema was a rare event.[15,16] Accordingly, some experts have recommended not imposing a limit on fluid removal as long as no chest pain develops during drainage,[17-19] and recent randomized trials studying different thoracentesis methods have adopted the same strategy.[20,21] Hence, further reduction in chest drain overuse could be safely achieved by omitting the massive effusion indication.

The pleural drainage order set and policy used in this study could be used in other centers with good reproducibility, even in centers without EMR. The order set can be easily adapted into a paper format, its use does not require special expertise, and drain indications are generalizable. The order set would be most useful, however, where some degree of drain overuse exists, for instance, where there is dissociation between clinical and technical expertise.

The limitations of this study include its single-center nature and the retrospective data collection. Assessment for chest drain indication was not blinded, and bias remains possible, although the criteria rely on easily identifiable and objective clinical parameters. Although it can be difficult to differentiate the impact of the order set from that of education initiatives, the improvements can be attributed to the former since educational efforts carried out before this study failed to modify practices. The long interval between pre- and post-intervention periods (caused by order-set technical development delays, EMR and radiology information systems' coordination, and mobilization of stakeholders to develop and implement the policy) could suggest that the changes observed were related to general institutional improvement over time. However, based on the immediate pre-implementation data included in the Figure, there was no trend of improvement over the years before implementation, and a drastic and sustained drop in drain use was seen after order-set implementation, arguing against that possibility. Barriers to the implementation of our interventions included the technical limitations of our EMR and its interface with the radiology information system, and the difficulty of changing the practice of hundreds of physicians and residents across multiple specialties. Furthermore, the lack of a prospective procedure registry made repeated audits cumbersome and labor-intensive.

CONCLUSIONS

Implementation of an EMR-based pleural drainage policy and order set led to a significant reduction in chest drain use, improved procedure selection according to clinical needs (evidenced by reduced use of very small drains in pleural infections), and reduced direct procedural costs. In institutions where small chest drains are the default drainage strategy for pleural effusions, this order set can reduce chest drain overuse.

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