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# The Relationship Between Chest Tube Size and Clinical Outcome in Pleural Infection

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***Background:*** **The optimal choice of chest tube size for the treatment of pleural infection is unknown, with only small cohort studies reported describing the efficacy and adverse events of different tube sizes.**

***Methods:*** **A total of 405 patients with pleural infection were prospectively enrolled into a multicenter study investigating the utility of fibrinolytic therapy. The combined frequency of death and surgery, and secondary outcomes (hospital stay, change in chest radiograph, and lung function at 3 months) were compared in patients receiving chest tubes of differing size ($\chi^2$, *t* test, and logistic regression analyses as appropriate). Pain was studied in detail in 128 patients.**

***Results:*** **There was no significant difference in the frequency with which patients either died or required thoracic surgery in patients receiving chest tubes of varying sizes (< 10F, number dying or needing surgery 21/58 [36%]; size 10-14F, 75/208 [36%]; size 15-20F, 28/70 [40%]; size > 20F, 30/69 [44%]; $\chi^2$trend, 1 degrees of freedom [*df*] = 1.21, *P* = .27), nor any difference in any secondary outcome. Pain scores were substantially higher in patients receiving (mainly blunt dissection inserted) larger tubes (< 10F, median pain score 6 [range 4-7]; 10-14F, 5 [4-6]; 15-20F, 6 [5-7]; > 20F, 6 [6-8]; $\chi^2$, 3 *df* = 10.80, *P* = .013, Kruskal-Wallis; $\chi^2$trend, 1 *df* = 6.3, *P* = .014).**

***Conclusions:*** **Smaller, guide-wire-inserted chest tubes cause substantially less pain than blunt-dissection-inserted larger tubes, without any impairment in clinical outcome in the treatment of pleural infection. These results suggest that smaller size tubes may be the initial treatment of choice for pleural infection, and randomized studies are now required.**

***Trial registration:*** **MIST1 trial ISRCTN number: 39138989.** ***CHEST 2010; 137(3):536–543***

**Abbreviations:** *df* = degrees of freedom; IQR = interquartile range; MIST1 = Multi-center Intrapleural Streptokinase Trial; MPS = median pain score

Pleural infection affects approximately 65,000 patients in the United States and United Kingdom each year.[1] It has a 22% mortality,[2] which is higher than that for myocardial infarction,[3] and a further 15% of patients require thoracic surgery to control their infection.[2] Selection of the optimal chest tube size is a key component of care for this disease, aiming to maximize drainage while minimizing patient discomfort and adverse events. The optimal tube size to achieve this balance is not known, and is vigorously debated. Currently advocated strategies for management include the use of larger-size tubes to facilitate the drainage of viscid pus,[4-6] and globally, this is the commonest practice.[7] A small-sized tube is often used

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initially by physicians and radiologists and is commonly reported as responsible for the need for later surgical drainage.[8] Despite this view, multiple case series report therapeutic success with smaller tubes, with apparently reduced pain.[9-19]

To date, there have been no published series that directly compare clinical outcomes, pain, and adverse events in patients treated with small-size chest tubes, defined in this report as 14F or smaller. The United Kingdom Medical Research Centre/British Thoracic Society Multi-center Intrapleural Streptokinase Trial (MIST1)[2] included 405 patients with pleural infection treated with a range of chest tube sizes and in whom clinical outcomes and adverse events were carefully recorded. This article describes the relationships between tube size and outcome in these patients, providing an evidence base for chest tube selection in pleural infection.

## Materials and Methods

### *The MIST1 Trial*

The MIST1 trial[2] was a double-blind, placebo-controlled comparison of intrapleural streptokinase with placebo in pleural infection. Intrapleural streptokinase was shown not to improve outcome, and so the results relating to chest tube size are not confounded by a treatment effect. Four hundred fifty-four patients were recruited from 52 UK centers, including both general and teaching hospitals. Patients with pleural fluid that was macroscopically purulent, positive on culture for bacterial infection, positive for bacteria on Gram staining, or with a pH below 7.2 in a patient with clinical evidence of infection were entered into the trial. Outcome measures included death or the need for thoracic surgery (to 12 months), the length of hospital stay, improvement in chest radiograph, $FEV_1$ and FVC at 3 months, and adverse events. Full details of the trial have been previously reported.[2] Ethical approval was obtained from the institutional review board, and all patients provided informed consent.

### *Chest Tube Choices*

The chest tube size and insertion method (either guide wire inserted or "blunt dissection" inserted) were selected by the managing physician, surgeon, or radiologist and reported on trial case report forms, with all data validated during trial monitoring. Where the tube size was < 14F, three times daily 30-mL saline flushes were used to maintain tube patency. Negative pressure of −20 cm $H_2O$, high volume, low pressure, suction was applied to tubes of all sizes.

### *Quantification of Chest Tube-Associated Pain*

Thirty-two of the recruiting centers offered a questionnaire describing pain associated with chest tube use to 128 subjects entering the trial who were judged not to be too ill to complete it. The questionnaire inquired about pain during chest tube insertion, while the tube was *in situ*, and during tube removal. For each pain component, the questionnaire was completed at the end of the event (immediately after tube insertion; at the end of the period with the chest tube *in situ*, just before chest tube removal; immediately after tube removal). The severity of pain during that component of care was scored on a four-point categorical scale (no pain, mild, moderate, or severe). The pain experienced during each of the components was summated to produce an overall pain score. Categorical pain scores were shown to be accurate and reproducible.[20-25] Whether the tube was prematurely displaced ("fell out") and replaced was also recorded.

### *Statistical Analysis*

*Efficacy Analyses:* The primary analysis explored the frequency of death or thoracic surgery at 12 months postrandomization by tube size. Where a patient had surgery and subsequently died, this was treated as one event. Secondary analyses examined death and thoracic surgery rates separately, hospital stay, residual chest radiograph shadowing, and dynamic lung function ($FEV_1$ and FVC) at 3 months.

A preplanned subgroup analysis of the primary end point was performed in subjects with frankly purulent/nonpurulent acidic fluid. Statistical tests used included $\chi^2$ analyses for proportions (Tables 1-4), the Mann-Whitney *U* test (see Table 4), Kruskal-Wallis tests for .2 group categorical data (see Table 3), and Kaplan Meier survival (Fig 1) and logistic regression analyses as appropriate (using SPSS 12.0.1; SPSS Inc.; Chicago, IL).

*Adverse Events:* For the analysis of tube-related pain, the overall summated pain score per patient was compared with scores for the individual contributing components (insertion, *in situ* pain, and removal) for large-size and small-size tubes. Serious and overall adverse event frequencies were compared for different tube sizes.

## Results

### *Subjects*

Detailed chest tube data, including exact tube size, were available on 405 (89%) of the 454 subjects (Table 1). Where tube size was not recorded, this was usually because the insertion had been by an admitting physician not involved in the trial. The distribution of the chest tube sizes used in the whole group and in the two insertion methodology subsets is shown in Table 2.

### *Efficacy Analyses*

*Primary Analysis:* There was no difference in the frequency with which patients either died and/or required thoracic surgery at 12 months in the groups receiving chest tubes of varying sizes (size < 10F, Number dying or needing surgery 21/58 [36%]; size 10-14F, 75/208 [36%]; size 15-20F, 28/70 [40%]; size > 20F, 30/69 [44%]); $\chi^2$trend, 1 degrees of freedom [*df*] = 1.21, *P* = .27) (Table 3). There was also no difference in the evolution of this end point over time (Fig 1) (log-rank test, $\chi^2$, 3 *df* = 1.58, *P* = .66).

Subjects were assessed for differences in factors known to be associated with increased mortality in pleural infection. The class of bacterial infection[26] (good-prognosis bacterial subclasses = all streptococci, mixed anaerobic, and culture negative; poor-prognosis bacterial subclasses = gram negative, mixed aerobes,

**Table 1—*Patient Baseline Characteristics in Each of the Chest Tube Size Groups***

| Patient Characteristic | Result by Tube Size, F (n = 405) | | | | Statistical Significance |
|---|---|---|---|---|---|
| | < 10 | 10-14 | 15-20 | > 20 | |
| Cases, N | 58 | 208 | 70 | 69 | |
| Sex, N (%) | | | | | |
| Male | 41 (71) | 144 (69) | 48 (69) | 43 (62) | $\chi^2$, 3 *df* = 1.37; *P* = .71 |
| Female | 17 (29) | 64 (31) | 22 (31) | 26 (38) | $\chi^2$, 3 *df* = 1.37; *P* = .71 |
| Concurrent anticoagulation, N (%) | 3 (5) | 24 (12) | 5 (7) | 9 (13) | $\chi^2$, 3 *df* = 3.35; *P* = .34 |
| Proportion of chest radiograph opacified by pleural effusion on chest radiograph, % median (IQR) | 40, (20-60) | 30, (20-60) | 40, (20-60) | 40, (20-70) | Kruskal-Wallis, 3 *df* = 2.17; P = .54 |
| Coexisting illness, N (%) | | | | | |
| Any chronic condition | 37 (64) | 141 (68) | 50 (71) | 49 (71) | $\chi^2$, 3 *df* = 1.12; *P* = .77 |
| Cardiac disease | 13 (22) | 53 (25) | 10 (14) | 16 (23) | $\chi^2$, 3 *df* = 3.75; *P* = .29 |
| Respiratory disease | 11 (19) | 41 (20) | 12 (17) | 7 (10) | $\chi^2$, 3 *df* = 3.38; *P* = .34 |
| Diabetes mellitus | 2 (3) | 17 (8) | 4 (6) | 6 (9) | $\chi^2$, 3 *df* = 1.99; *P* = .57 |
| Excess alcohol intake | 5 (9) | 18 (9) | 8 (11) | 8 (12) | $\chi^2$, 3 *df* = 0.86; *P* = .83 |
| Joint disease | 12 (21) | 83 (40) | 23 (33) | 22 (32) | $\chi^2$, 3 *df* = 7.87; *P* = .048 |
| Gastroesophageal disease | 3 (5) | 21 (10) | 3 (4) | 2 (3) | $\chi^2$, 3 *df* = 5.8; *P* = .12 |
| Neurologic disease | 4 (7) | 22 (11) | 5 (7) | 7 (10) | $\chi^2$, 3 *df* = 1.23; *P* = .75 |
| Kidney disease | 2 (3) | 12 (6) | 3 (4) | 0 (0) | $\chi^2$, 3 *df* = 4.38; *P* = .22 |
| Liver disease | 2 (3) | 32 (15) | 9 (13) | 9 (13) | $\chi^2$, 3 *df* = 5.78; *P* = .12 |
| Other | 5 (9) | 25 (12) | 7 (10) | 8 (12) | $\chi^2$, 3 *df* = 0.64; *P* = .89 |
| Pleural-fluid characteristic | | | | | |
| Visibly purulent, N (%) | 42 (72) | 164 (79) | 58 (83) | 65 (94) | $\chi^2$ 3 *df* = 11.47; *P* = .009 |
| Gram-positive for bacteria, N (%) | 19 (33) | 87 (42) | 30 (43) | 28 (41) | $\chi^2$ 3 *df* = 1.76; *P* = .63 |
| Culture positive for bacteria, N (%) | 16 (28) | 78 (38) | 22 (31) | 25(36) | $\chi^2$ 3 *df* = 2.41; *P* = .49 |
| pH, mean (SD) | 6.89 (0.29) | 6.87 (0.41) | 6.82 (0.44) | 6.64 (0.75) | Kruskal-Wallis, 3 *df* = 2.33; *P* = .51 |
| Glucose, mmol/L (mean SD) | 2.1 (2.3) | 3.3 (4.1) | 2.2 (2.7) | 4.3 (4.5) | Kruskal-Wallis, 3 *df* = 6.23; *P* = .10 |
| Lactate dehydrogenase, International Unit/L median (IQR) | 16,580 (34,700) | 9,820 (22,280) | 20,400 (28,300) | 25,580 (37,550) | Kruskal-Wallis, 3 *df* = 14.5; *P* = .002 |
| Known risk factors for death/surgery at randomization | | | | | |
| Age, mean SD | 55 (18) | 61 (17) | 61 (19) | 60 (18) | Two-way ANOVA, F = 2.03; *P* = .11 |
| Albumin, mean SD | 28 (6) | 30 (7) | 26 (6) | 25 (6) | Two-way ANOVA, F = 9.20; *P* < .001 |
| Diastolic blood pressure, mm Hg (mean SD) | 71 (13) | 70 (12) | 68 (10) | 70 (12) | Two-way ANOVA, F = 0.68; *P* = .56 |
| Bacteriology, N (%) | | | | | |
| Good prognosis | 47 (81) | 164 (80) | 52 (80) | 54 (83) | $\chi^2$ 3 *df* = 0.32; *P* = .95 |
| Poor prognosis | 11 (19) | 41 (20) | 13 (20) | 11 (17) | $\chi^2$ 3 *df* = 0.32; *P* = .95 |
| Infection Source, N (%) | | | | | |
| Hospital | 10 (18) | 45 (22) | 18 (26) | 16 (23) | $\chi^2$ 3 *df* = 1.29; *P* = .73 |
| Community | 47 (82) | 163 (78) | 52 (74) | 53 (77) | $\chi^2$ 3 *df* = 1.29; *P* = .73 |

Data include the frequency of markers of increased mortality[26,27] (please refer to "Efficacy Analyses" section for further explanation). Significant differences are highlighted and discussed in the "Results" section. Results here based on the totals available. ANOVA = analysis of variance; *df* = degrees of freedom; IQR = interquartile range.

and staphylococci, including methicillin-resistant *staphylococcus aureus*) has been associated with outcome in pleural infection. In addition, clinical criteria at baseline[27] that are associated with poor prognosis include a raised urea level, increasing age, a low albumin level, low diastolic blood pressure, and hospital-acquired infection (Table 1). There were no significant differences between tube size groups in these parameters, except for the baseline albumin level (Table 1).

Logistic regression was used to adjust for differences in baseline covariates known to predict mortality in the analysis of the primary end point.[26,27] After adjustment, there remained no relationship between chest tube size and mortality or surgery (*P* value for contribution to the model by tube size = .96).

The primary outcome measure (death and surgery combined) was analyzed for each tube size group separately, according to whether the patient had received either streptokinase or placebo, and there

**Table 2—*Chest Tube Sizes and Insertion Method***

| Tube Size, F | Total Tubes, No. (%) | Guide Wire Insertion, N (%) | Blunt Dissection Insertion, N (%) |
|---|---|---|---|
| < 10 | 58 (14) | 55 (95) | 3 (5) |
| 10-14 | 208 (51) | 198 (95) | 10 (5) |
| 15-20 | 70 (17) | 12 (17) | 58 (83) |
| > 20 | 69 (17) | 0 (0) | 69 (100) |
| Total | 405 | 265 (65) | 140 (35) |

See Table 1 for expansion of abbreviation. Statistical significance is $\chi^2$, 3 *df* = 303; *P* < .001.

**Table 3—*The Effect of Chest Tube Size on Primary (Death and Surgery Combined) and Secondary Clinical Outcomes***

| Outcome | Tube Size, F | | | | Statistical Significance |
|---|---|---|---|---|---|
| | <10 | 10-14 | 15-20 | >20 | |
| Death and surgery combined, N (%) | 21/58 (36) | 75/ 208 (36) | 28/70 (40) | 30/69 (44) | $\chi^2$trend, 1 *df* = 1.21, *P* = .27 |
| Death at 1 y, N (%) | 10/58 (17) | 46/ 208 (22) | 18/70 (25) | 17/69 (25) | $\chi^2$, 3 *df* = 1.53, *P* = .67 |
| Surgery at 1 y, N (%) | 11/58 (19) | 35/208 (17) | 13/70 (19) | 13/69 (19) | $\chi^2$, 3 *df* = 0.27, *P* = .97 |
| Hospital stay,[a] d (SD) | 26 (29) | 24 (32) | 31 (39) | 28 (23) | Two-way ANOVA, 3 *df*, F = 1.04, *P* = .37 |
| $FEV_1$ at 3 mo, L (SD) | 2.46 (1.0) | 2.16 (0.79) | 2.30 (0.88) | 2.15 (0.90) | Two-way ANOVA, 3 *df*, F = 1.17, *P* = .32 |
| FVC at 3 mo, L (SD) | 3.30 (1.19) | 2.98 (0.98) | 3.18 (1.13) | 2.84 (1.00) | Two-way ANOVA, 3 *df*, F = 1.42, *P* = .24 |
| Reduction in chest radiograph abnormality from baseline at 3 mo,[b] median % hemithorax (IQR) | 90, (77-90) | 90, (77-90) | 90, (52-90) | 90, (77-90) | Kruskal-Wallis, $\chi^2$, 3 *df* = 2.93, *P* = .40 |

See original MIST1 publication[2] for details. See Table 1 for expansion of the abbreviations.
[a]Hospital stay = duration of admission in total, including period postrandomization to MIST1 study.
[b]Categorical score obtained by blinded radiologist review of chest radiographs.

was no difference found in the outcomes (data not shown).

*Secondary Analyses:* There was no difference at the 5% level in the frequency of death or surgery alone, length of hospital stay postrandomization, or $FEV_1$, FVC, or residual chest radiograph abnormality at 3 months in groups treated with tubes of varying size (Table 3). The method of chest tube insertion was not associated with any differences in clinical outcome (Table 4).

*Subgroup Analysis:* There was a statistically significant difference in the frequency with which patients either died or required thoracic surgery at 12 months in the groups receiving chest tubes of varying size in patients with purulent pleural fluid, favoring smaller size tubes (purulent fluid: size < 10F, No. dying or needing surgery 12/42 [29%]; size 10-14F, 55/164 [34%]; size 15-20F, 25/58 [43%]; size > 20F, 29/65 [45%]; $\chi^2$trend, 1 *df* = 4.3, *P* = .04.). There was a borderline significant difference in patients with nonpurulent pleural fluid (nonpurulent fluid: size < 10F, Number dying or needing surgery 9/16 [56%]; size 10-14F, 20/44 [46%]; size 15-20F, 3/12 [25%]; size > 20F, 1/4 [25%]; $\chi^2$trend, 1 *df* = 3.0, *P* = .08).

*Adverse Event Analyses:* Overall pain scores were higher in patients treated with larger-size chest tubes (size < 10F, median pain score [MPS] 6 [range 4-7]; size 10-14F, MPS 5 [4-6]; size 15-20F, MPS 6 [5-7]; size > 20F, MPS 6 [6-8]; $\chi^2$, 3 *df* = 10.80, *P* = .013, Kruskal-Wallis; $\chi^2$trend, 1 *df* = 7.29, *P* = .008). Pain scores were higher in those treated with blunt-dissection-inserted tubes compared with guide-wire-inserted tubes (blunt dissection MPS 7, interquartile range [IQR] 5-9; guide wire MPS 5, IQR 3 to 8; Mann-Whitney *U* test, *P* = .006). Because the size of the drain inserted and the insertion technique were highly correlated ($\chi^2$, 3 *df* = 303, *P* < .0001), no further separate analysis of insertion technique (as opposed to tube size) was conducted.

The greater pain caused by larger-size tubes was the result of increased pain during the insertion of the tube and pain while the tube was *in situ*, with no pain difference during tube removal (insertion: size < 10F, MPS 2 [IQR 1-2]; size 10-14F, MPS 2 [IQR 1-3]; size 15-20F, MPS 2 [IQR 1-3]; size > 20F, MPS 2, [IQR 2-3]; $\chi^2$, 3 *df* = 8.12, *P* = .044, Kruskal-Wallis; $\chi^2$trend, 1 *df* = 7.2, *P* = .009. *in situ*: size < 10F, MPS 2 [IQR 1-3]; size 10-14F, MPS 2 [IQR 1-2]; size 15-20F, MPS 2 [IQR 2 to 3]; size > 20F, MPS 2

**Table 4—*Relationship Between the Technique of Chest Tube Insertion and Secondary Clinical Outcomes***

| Outcome | Seldinger Insertion | Blunt Dissection Insertion | Statistical Significance |
|---|---|---|---|
| Combined death and surgery, N (%) | 105/265 (37) | 62/140 (41) | $\chi^2$ 1 *df* = 0.66; OR 1.17; 95% CI 0.78-1.75; *P* = .42 |
| Death at 1 y, N (%) | 62/265 (22) | 34/140 (23) | $\chi^2$ 1 *df* = 0.02; OR 1.04; 95% CI 0.64-1.65; *P* = .89 |
| Surgery at 1 y, N (%) | 50/265 (17) | 30/140 (20) | $\chi^2$ 1 *df* = 0.27; OR 1.14; 95% CI 0.69-1.89; *P* = .61 |
| Hospital stay, d (SD) | 26 (36) | 26 (21) | *P* = .061 (Mann-Whitney) |
| $FEV_1$ at 3 mo, L (SD) | 2.19 (0.84) | 2.28 (0.89) | Diff = 0.11; 95% CI −0.34-0.11; *P* = .48 |
| FVC at 3 mo, L (SD) | 3.02 (1.03) | 3.05 (1.05) | Diff = 0.08; 95% CI −0.35-0.20; *P* = .92 |
| Reduction in chest radiograph from baseline at 3 mo, median % hemithorax (IQR)[a] | 90 (77-90) | 90 (77-90) | *P* = .81 (Mann-Whitney) |

See Table 3 for related data. See original MIST1 publication[2] for details. OR = odds ratio; Diff = difference. See Table 1 for expansion of other abbreviations.
[a]Categorical score obtained by blinded radiologist review of chest radiographs.

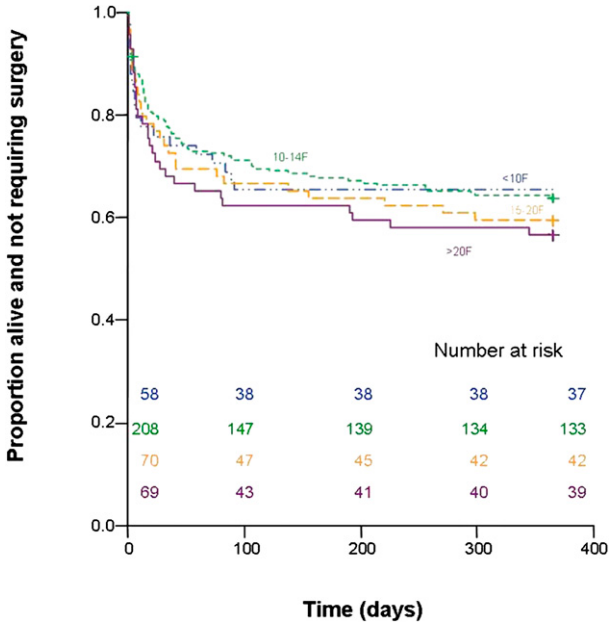


FIGURE 1. The proportion of patients alive and not having required surgery over 12 months in patients treated with chest tubes of different sizes.

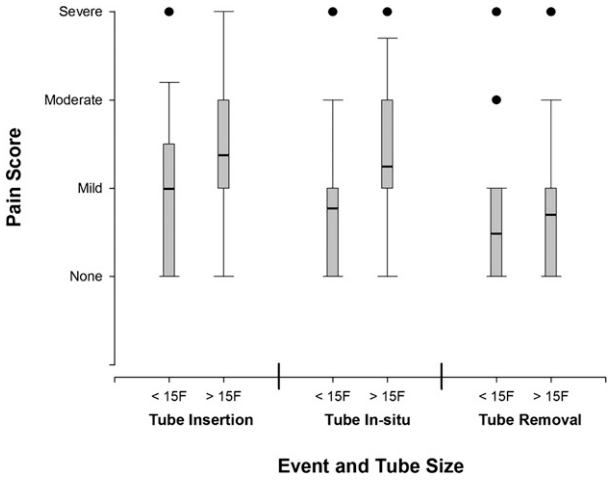


FIGURE 2. The intensity of pain reported by subjects receiving a chest tube larger than and smaller than the median size for the study group (<15F/>15F) at different stages of care: chest tube insertion, chest tube *in situ*, and during tube removal. The increased pain experienced with the larger-size tubes is felt during insertion and while the tube is *in situ* (see text for details). Horizontal bars indicate the mean pain score per group; • represent outliers.

[IQR 2-3]; $\chi^2$, 3 $df = 11.75$, $P = .008$, Kruskal-Wallis; $\chi^2$trend, 1 $df = 6.2$, $P = .015$. removal: size < 10F, MPS 2 [IQR 1-2]; size 10-14F, MPS 1 [IQR 1-2]; size 15-20F, MPS 2 [IQR 1-2]; size > 20F, MPS 1 [IQR 1-2]; $\chi^2$, 3 $df = 2.7$, $P = .44$, Kruskal-Wallis; $\chi^2$trend, 1 $df = 1.0$, $P = .31$ (Fig 2).

There was no significant difference in the frequency with which tubes were displaced from the chest ("fell out") between chest tube sizes (size < 10F, No. displaced 3/16 [19%]; size 10-14F, 14/61 [23%]; size 15-20F, 0/19 [0%]; size > 20F, 4/23 [17%]; $\chi^2$, 3 $df = 5.02$, $P = .18$). There was no difference in the frequency of any other adverse events (data not shown).

## DISCUSSION

Our study has shown that the clinical outcome in patients treated with different chest tube sizes for pleural infection is similar, but smaller-size tubes cause less pain.

This difference in pain is substantial and clinically significant. During chest tube insertion and while the tube was *in situ*, 22/41 (54%) of patients receiving a chest tube ≥15F experienced moderate/severe pain, compared with only 21/77 (27%) of patients treated with a tube <15F ($\chi^2$, 1 $df = 8.0$, $P = .005$). Thus, 27% of patients with larger-size tubes experienced moderate to severe pain that might have been avoided by small-size-tube use (Fig 2). This difference is comparable to the difference in pain intensity experienced by patients receiving a placebo compared with those receiving 5 mg intravenous morphine after major surgery,[28] where 31% of patients given a placebo experienced clinically significant pain that could have been avoided by the use of morphine. The chest-tube-pain difference is also similar to the difference in pain intensity after receiving a placebo or strong nonsteroidal analgesia for abdominal/pelvic[29] or major orthopedic[30] surgery.

It is possible that the tube insertion technique is associated with different amounts of experienced pain (eg, blunt dissection insertion causes more tissue trauma). Because the insertion technique (guide wire or blunt dissection) is closely coassociated with tube size ($\chi^2$, 3 $df = 303$, $P < .0001$), it is not possible to establish from this data whether the difference in pain intensity relates to the size of the tube, the technique of insertion, or both. Specific studies assessing insertion technique, tube size, and pain are required to definitively answer this question.

A potential limitation to the pain results here demonstrated is that not all patients were able to complete the pain questionnaire. This study did not specifically record the number of patients in whom the pain questionnaire was offered who were "too unwell" to complete it. However, this number is likely to have been small and not likely to have materially altered the significance of the results here demonstrated.

A general change to the use of smaller-sized tubes might not be appropriate if there was evidence for a therapeutic benefit from using larger tubes. From our data, there is no suggestion of any therapeutic disadvantage associated with smaller-size tubes (Fig 1).

Comparing the rate of surgery or death in those treated with a tube size < 15F (36%) with those treated with a size > 15F (41%), an advantage to the use of the larger size of 5% can be excluded with a 95% CI. Because the combined mortality and surgery rate at 12 months is 38%,[2] this implies that if there is an advantage to large-size tubes, the number of patients needing to be treated with a large-size tube to prevent one death or operation is at least 50 (95% CI).

We have assessed whether the known risk factors predicting mortality in patients with empyema[26,27] might have confounded this analysis. The only mortality predictor that was associated with tube size was serum albumin, with a lower albumin level in those patients with larger-size tubes (although this result may have arisen by chance). Logistic regression adjusting for these known outcome predictors does not change the result of the primary analysis.

The clinical outcome data available for this cohort has also allowed the exploration of the effect of tube size and insertion technique on hospital stay, dynamic lung function, and chest radiograph abnormality after recovery. Again, there is no suggestion of a differential outcome in any of these variables.

The subgroup analysis of the frequency of death or surgery in patients with purulent pleural fluid or complicated parapneumonic effusion also shows no advantage to an increasing chest tube size. In fact, there is a small advantage to the use of smaller-size tubes in patients with frankly purulent fluid. This result provides some support for the use of the smaller-size (often image guided) drainage technique advocated elsewhere,[10,11,15,16,18,19,31-34] although the statistical significance of this relationship is only borderline ($P = .04$), especially given the multiple tests conducted here. Whether there truly is an advantage to smaller-size tubes, these data are reassuring in that there is no disadvantage to their use. Although not recorded for the purposes of this study, placement of smaller-sized chest tubes under image guidance may contribute to the efficacy in clinical outcome demonstrated here.

To our knowledge, this is the first study to produce comparative data comparing efficacy and adverse events in different tube sizes in pleural infection. Two smaller studies in abdominal abscesses were previously reported,[14,17] and these reports are consistent with our results, showing no advantage from drainage with larger tubes. Previous studies in pleural infection regarding subjects treated with a range of chest tube sizes did not explore the effect of these differences on clinical outcome,[13,35-44] with the exception of Thomson et al,[45] where smaller-size tubes were associated with a shorter hospital stay in pediatric patients with pleural infection, suggesting a possible advantage in favor of smaller-size tubes in this population. There are also a large number of noncomparative series assessing the use of small-size tubes that report high rates of drainage success with this modality.[10,11,15,16,18,19,31-34] One previous retrospective study[46] analyzing outcomes in 52 patients with empyema who were treated with smaller sized chest tubes showed a nonsignificant trend toward increased success using 12F tubes (vs 10F and 8F tubes) for purulent pleural fluid, with an overall treatment success rate (73%) comparable to our study findings.

Although there is no significant difference in the rate of unplanned chest tube displacement ("falling out"), tubes < 15F showed a borderline trend toward higher rates of displacement ($\chi^2$, 1 $df = 2.78$, $P = .096$). If this result is real, the frequency of chest tube displacement is 2.4-fold higher with smaller-size than with larger-size tubes, equating to 13 extra chest tube replacement procedures per 100 patients. This would be an unacceptable excess displacement rate, and improved techniques to maintain tube stability would be required to maximize the clinical benefit that these data suggest otherwise attends the use of smaller-size tubes.

## Conclusion

To our knowledge, this is the first prospective study to directly compare outcomes in pleural infection with different chest tube sizes. The results demonstrate that in a large cohort of patients with pleural infection treated with a range of chest tube sizes and different insertion techniques, smaller-size tubes, 14F or smaller (mostly guide-wire inserted), cause much less pain than larger-size tubes (mostly blunt-dissection inserted), without impairing clinical outcome. Should these results be borne out in randomized prospective studies, these data suggest that a change to smaller-size tubes would substantially reduce the pain experienced by patients being treated for pleural infection, without reducing efficacy. Randomized studies prospectively assessing tube size efficacy, tube placement technique, and pain in the treatment of pleural infection are now required.


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