Acute poststernotomy mediastinitis managed with debridement and closed-drainage aspiration: Factors associated with death in the intensive care unit

Jean-Louis Trouillet, MD^a
 Albert Vuagnat, MD^a
 Alain Combes, MD^a
 Valeria Bors, MD^b
 Jean Chastre, MD^a
 Iradj Gandjbakhch, MD^b
 Claude Gibert, MD^a

Dr Trouillet

From Service de Réanimation Médicale^a and Service de Chirurgie Thoracique et Cardiovasculaire,^b Hôpital La Pitié-Salpêtrière Assistance Publique-Hôpitaux de Paris, Paris, France.

Received for publication Dec 8, 2003; revisions received July 2, 2004; accepted for publication July 13, 2004.

Address for reprints: Jean-Louis Trouillet, MD, Service de Réanimation Médicale, Pr Gibert, Institut de Cardiologie, Hôpital Pitié-Salpêtrière 47-83 boulevard de l'Hôpital, 75651 Paris Cedex 13, France (E-mail: jean-louis.trouillet@psl.ap-hop-paris.fr).

J Thorac Cardiovasc Surg 2005;129:518-24
 0022-5223/\$30.00

Copyright © 2005 by The American Association for Thoracic Surgery

doi:10.1016/j.jtcvs.2004.07.027

Objective: The purpose of the study is to describe an intensive care unit's experience in the treatment of poststernotomy mediastinitis and to identify factors associated with intensive care unit death.

Methods: Over a 10-year period, 316 consecutive patients with mediastinitis occurring less than 30 days after sternotomy were treated in a single unit. First-line therapy was closed-drainage aspiration with Redon catheters. Variables recorded, including patient demographics, underlying disease classification, clinical and biologic data available at intensive care unit admission and day 3, and their association with intensive care unit mortality, were subjected to multivariate analyses.

Results: Intensive care unit mortality (20.3%) was significantly associated with 5 variables available at admission: age greater than 70 years (odds ratio, 2.70), operation other than coronary artery bypass grafting alone (odds ratio, 2.59), McCabe class 2/3 (odds ratio, 2.47), APACHE II score (odds ratio, 1.12 per point), and organ failure (odds ratio, 2.07). After introducing day 3 variables into the logistic regression model, independent risk factors for intensive care unit death were as follows: age greater than 70 years, operations other than coronary artery bypass grafting alone, McCabe class 2/3, APACHE II score, mechanical ventilation still required on day 3, and persistently positive bacteremia. For patients receiving mechanical ventilation for less than 3 days, mortality was very low (2.4%). In contrast, for patients receiving mechanical ventilation for 3 days or longer, mortality reached 52.8% and was associated with non-coronary artery bypass grafting cardiac surgery, persistently positive bacteremia, and underlying disease.

Conclusions: In patients requiring intensive care for acute poststernotomy mediastinitis, age, type of cardiac surgery, underlying disease, and severity of illness at the time of intensive care unit admission were associated with intensive care unit death. Two additional factors (mechanical ventilation dependence and persistently positive bacteremia) were identified when the analyses were repeated with inclusion of day 3 patient characteristics.

Mediastinitis is a severe complication of median sternotomy responsible for significant morbidity and mortality in adults. Thirty years ago, these wounds were treated with open packing or continuous mediastinal irrigation.^{1,2} The poor results obtained in earlier studies, with mortality approaching 50%, encouraged surgeons to develop other techniques, such as complex plastic surgery procedures with muscle flaps.³ In 1989, Durandy and

colleagues⁴ proposed a simple, primary closed-drainage technique with small multiperforated rigid catheters (Redon catheters) to drain all infected areas after meticulous wound debridement. The results of our previous experience suggested that this first-line treatment was effective.⁵

Compared with other surgical techniques, closed drainage with Redon catheters has several advantages: it is simple and rapidly put in place, it is less work intensive for nurses, and it leaves a discreet scar. Thus first-line surgical treatment of mediastinitis has been standardized with this technique for over 10 years in all cardiothoracic centers in Paris, France, and, more recently, in other European centers.⁶

However, although technical procedures have been described in detail and the epidemiology of deep sternal wound infections has been extensively studied,⁷⁻¹⁰ few reports deal with prognostic factors in patients with mediastinitis.^{11,12} Most of the factors considered in those previous studies were related to the initial cardiac surgery. The heterogeneity in antibiotic regimens and in surgical techniques, which are used according to each team's experience in the absence of consensual guidelines,^{2-5,13-16} contributes to the difficulty of performing such studies.

Over a 10-year period, we prospectively collected specific data that might have an effect on the outcomes of patients with acute poststernotomy mediastinitis. Therefore the aim of this study is to describe the experience of a single intensive care unit (ICU) in the treatment of poststernotomy mediastinitis with closed-drainage aspiration with Redon catheters and to identify independent factors associated with ICU death.

Methods

Patients and Management of Mediastinitis

This observational study was conducted in a single ICU located at Bichat Hospital, a tertiary care center. Between January 1, 1991, and October 31, 2001, 353 patients were referred to our ICU for acute mediastinitis after cardiac surgery. Mediastinitis was defined as deep wound infection associated with sternal osteomyelitis with or without infected retrosternal space that required surgical debridement. Confirmation of mediastinal infection was obtained on the basis of positive results of direct examination and culture of either transcutaneous needle aspirates of the deep mediastinum before surgical debridement or surgical material. The diagnosis was also retained, despite negative cultures, when intraoperative observations were unequivocal (eg, sternal disjunction with necrotic tissue and mediastinal pus). Inclusion criteria for the present study were as follows: mediastinitis occurring within 30 days after cardiac surgery and requiring ICU transfer, management with surgical debridement performed just before or within 24 hours after ICU admission, and closed-drainage aspiration with Redon catheters. As described in detail elsewhere,⁵ 3 to 10 Redon catheters (B. Braun Melsungen, AG) were placed in all infected areas, including the mediastinal cavity and the dissected subcutaneous chest wall area. Once the sternum had been rewired and the skin closed, each catheter was connected to a bottle (Drainobag; B.

TABLE 1. Microbiology of the 316 cases of mediastinitis included in the study

Main causative microorganism*	Patients, n (%)	Polymicrobial infections,† (%)
MSSA	141 (44.6)	1.3
MRSA	49 (15.5)	1.4
CNS	41 (13)	9.7
GNB	52 (16.5)	2.9
Streptococci	15 (4.7)	2.7
Miscellaneous	7 (2.2)	1.4
Unidentified	11 (3.5)	

MSSA, Methicillin-susceptible *Staphylococcus aureus*; MRSA, methicillin-resistant *Staphylococcus aureus*; CNS, coagulase-negative staphylococci; GNB, gram-negative bacilli.

*See text for definition.

†At least 1 other microorganism was isolated from 50 patients along with the main causative microorganism in some of the initial samples.

Braun Melsungen, AG) in which a strong negative pressure (600-700 mm Hg) was maintained. The collecting bottles were changed daily. Three times a week, the effluents collected in the bottles were cultured. When the culture results were negative and the volume of the effluent was less than 20 mL/24 hours, catheters were progressively removed ($\frac{2}{3}$ cm daily). Antibiotic therapy was initiated at the time of surgical debridement and was adapted to the microorganisms isolated from effluent samples. As soon as *Staphylococcus* species-induced mediastinitis was suspected, intravenous antibiotic therapy combining cefamandole, vancomycin, and gentamicin was instituted, except for patients allergic to β -lactams who received vancomycin and gentamicin. Thereafter, antibiotic therapy was given for 6 weeks. Methicillin-sensitive *Staphylococcus aureus* mediastinitis was treated with cefamandole for 3 weeks and gentamicin for 3 to 5 days, with the latter replaced by oral rifampin and fluoroquinolone. Methicillin-resistant *S aureus* infections were treated for 6 weeks with vancomycin and 1 to 2 other antibiotics on the basis of microbiologic susceptibility, as were coagulase-negative staphylococci. The antibiotic regimen for other infections was chosen according to the results of susceptibility testing.

Finally, 17 (4.8%) of the 353 patients were initially treated with the open technique. Among them, 14 had been referred to our ICU during the first year (1991) of the study period, when surgical teams transferring patients to our unit were using indiscriminately open and closed techniques. In the 3 other patients, the thorax was left open because of extensive necrotic lesions. Eventually, 8 of the 17 patients died. Among 336 patients first treated with closed-drainage aspiration with Redon catheters, 20 were transferred to our ICU 30 days or more after the initial cardiac surgery; none of them died. Therefore, 316 patients hospitalized within 30 days after initial cardiac surgery were included in the present study. Initial surgical procedures were distributed as follows: 185 (58.5%) coronary artery bypass grafting (CABG) operations, 68 (21.5%) valve operations, 43 (13.6%) CABG plus valve replacements, 6 (1.9%) heart transplantations, and 14 (4.4%) other operations (eg, aortic dissection and pericardial surgery). The mean $\pm$ SD incubation time was 13 ± 5.2 days (median, 13 days). The microorganisms responsible for mediastinitis are listed in Table 1.

Data Collection

Each patient's hospital chart was constituted prospectively, and the following data within 24 hours of ICU admission were recorded: age; sex; type of initial cardiac operation classified into 5 categories as detailed above; mediastinitis incubation time, defined as the interval between the initial cardiac surgery and surgical debridement for mediastinitis; severity of the underlying medical condition stratified according to the criteria of McCabe and Jackson¹⁷ as fatal (class 3), ultimately fatal (class 2), or not fatal (class 1); APACHE II score¹⁸; and number of organ dysfunctions according to the definitions established in the ODIN model.¹⁹

In addition, the patients were reassessed on day 3 after ICU admission. This time point was chosen because it takes at least 48 hours to get valuable bacteriologic data and because mechanical ventilation (MV) duration of greater than 48 hours is considered prolonged respiratory support and associated with high rates of adverse events after cardiac surgery.²⁰ Four variables were therefore recorded on day 3: microorganism responsible for mediastinal infection classified as *S aureus* or other microorganism; presence of methicillin-resistant *S aureus*; persistently positive bacteremia, defined as 2 or more positive blood cultures drawn more than 12 hours apart with the microorganism responsible for infection; and requirement for MV. In the case of polymicrobial infection, the microorganism found in all mediastinal samples and blood cultures was considered to be the main causative microorganism. When a *Staphylococcus* organism was present, it was considered the main causative microorganism.

Outcome measures included the following: in-ICU mortality; duration of MV; duration of ICU stay; time required to sterilize mediastinal fluid, calculated as the interval between the day of debridement and the first day at which the collected mediastinal fluid was sterile; duration of Redon drainage; and failure of treatment to eradicate local infection, defined as the need for redebridement. Life-threatening complications, defined as definite secondary endocarditis of an operated valve and massive mediastinal hemorrhage occurring after initial mediastinal debridement, were also noted. Mediastinitis-related death was defined as death occurring as a consequence of massive mediastinal hemorrhage, associated prosthetic valve endocarditis, or uncontrolled sepsis caused by mediastinitis and leading to multiorgan failure.

Statistical Analyses

Univariate analysis was performed to assess the effects on ICU survival of clinical characteristics known within 24 hours of ICU admission or available 3 days after ICU admission. Continuous variables, expressed as means $\pm$ SD, were compared with the Student *t* test or the Mann-Whitney *U* test as appropriate. Categorical variables, expressed as percentages, were compared with the χ^2 test or the Fischer exact test, as appropriate.

Second, 3 separate multivariate logistic regression analyses of risk factors for ICU mortality were performed: for the entire population of patients, analyzing variables known within 24 hours or 3 days after ICU admission, and on day 3 for the subgroup of patients still mechanically ventilated because ICU mortality was very low when patients were weaned off the ventilator within 3 days after debridement. Variables with *P* values of .05 or less according to the univariate analysis were included in the multivariate models. Thereafter, the analyses were repeated, including all

candidate risk factors in the multivariate models. Variables were considered to be independent risk factors for ICU death when the final multivariate *P* value was less than .05. The discriminating ability of each model was assessed by using the area under the receiver operating characteristic curve. Calibration of each model was assessed with the Hosmer-Lemeshow goodness-of-fit statistic.

Additionally, these models were tested when the population was randomly divided into a derivation cohort, including 65% of the patients, and a validation cohort, including the rest of the patients. Finally, stability of the obtained models was evaluated by using the bootstrap procedure, which generated a random series of 1000 samples, and thereafter, mean parameter estimates as discriminant values were calculated.

All analyses were conducted with the SAS 6.12 software (SAS Institute).

Results

Demographic and Clinical Characteristics

Patient characteristics are summarized in Table 2. Sixty-four (20.3%) patients died, and death was directly attributable to mediastinitis in 33 (10.4%) patients (Table 3). Throughout the entire study, mortality rates remained stable, regardless of the year of diagnosis (*P* = .65) or the surgeon performing the debridement (*P* = .75).

Univariate Analyses and Risk Factors for in-ICU Mortality

Results of comparisons of ICU survivors and nonsurvivors are detailed in Table 2. All variables known within 24 hours of ICU admission, except incubation time, were significantly associated with in-ICU mortality. For the univariate analysis concerning factors available as of day 3, 2 nonsurvivors were excluded because they died of septic shock with multiorgan failure on the day of admission: the first succumbed to a methicillin-sensitive *S aureus* infection with persistent bacteremia and the second to a coagulase-negative staphylococcal infection.

On day 3 after ICU admission, all 4 newly available variables were significantly associated with a poor prognosis (Table 2). Concerning MV and prognosis, 5 (2.4%) of 206 patients weaned off MV before day 3 died versus 57 (52.8%) of 108 patients requiring MV for 3 or more days after debridement.

Multivariate Analyses

When logistic regression analysis was applied to the factors available within 24 hours of admission, the 5 independently associated with in-ICU mortality (Table 4), with the exception of the type of operation, were linked to the severity of the underlying disease and the severity of the acute illness. The multivariate analysis, including variables available as of day 3, retained 5 factors as being independently and significantly associated with mortality: 3 known within the first 24 hours in the ICU and identified in the prior analysis (age >70 years, operation other than CABG alone, and

TABLE 2. Demographic and clinical characteristics of survivors and nonsurvivors available within 24 hours of or 3 days after ICU admission: Univariate analyses

Variables	Survivors	Nonsurvivors	P value
Within 24 h of ICU admission, n (%)	252 (79.7)	64 (20.3)	
Age			
Mean $\pm$ SD, y	61.1 $\pm$ 12.6	67.0 $\pm$ 13.9	.001
>70 y, n (%)	63 (25)	33 (51.6)	< .0001
Male sex, n (%)	187 (74.2)	36 (56.3)	.001
McCabe and Jackson class, n (%)			
2/3*	53 (21.0)	35 (54.7)	< .0001
1, nonfatal	199 (79)	29 (45.3)	
Incubation, mean $\pm$ SD, d	13.3 $\pm$ 5.2	12.0 $\pm$ 5.1	.08
Initial operation CABG alone, n (%)	157 (62.3)	28 (43.8)	.007
APACHE II score, mean $\pm$ SD	13.8 $\pm$ 6.2	24.0 $\pm$ 7.8	< .0001
Organ failure, mean $\pm$ SD	0.9 $\pm$ 1.0	2.4 $\pm$ 1.2	< .0001
Day 3 after ICU admission, n	252	62†	
Causative microorganism			
<i>S aureus</i> , n (%)	144 (57.1)	46 (71.9)	.03
MRSA, n (%)	33 (13.1)	16 (25.8)	.03
MV $\geq$ 3 d, n (%)	51 (20.3)	57 (91.9)	< .0001
Persistently positive bacteremia,‡ n (%)	126 (50)	48 (77.4)	.0001

ICU, Intensive care unit; CABG, coronary artery bypass grafting; MRSA, methicillin-resistant *Staphylococcus aureus*; MV, mechanical ventilation.

*Rapidly or ultimately fatal.¹⁷

†Two patients died within 2 days of intensive care unit admission and were not included (nonsurvivors, n = 62).

‡Persistently positive bacteremia, more than 2 positive blood cultures drawn more than 12 hours apart.

TABLE 3. Causes of death

Cause of death	No. of cases (%)
Initial shock with multiorgan failure related to mediastinitis*	23 (35.9)
Late-onset shock with multiorgan failure not related to uncontrolled mediastinal infection	10 (15.6)
Associated endocarditis*	6 (9.4)
Major local hemorrhage*	4 (6.3)
Mediastinal	3
Hemothorax	1
Neurologic coma	5 (7.8)
Late-onset nosocomial infection	11 (17.2)
Ventilator-associated pneumonia caused by <i>Pseudomonas aeruginosa</i> or methicillin-resistant <i>S aureus</i>	8
Bacteremia caused by other microorganisms than initial microorganism (not originating from the mediastinum)	2
Acute cardiac failure	5 (7.8)

*Mediastinitis-related death.

McCabe and Jackson class 2/3 [rapidly or ultimately fatal]) plus persistently positive bacteremia and MV for 3 or more days (Table 4).

In light of the very low mortality rate for patients weaned off MV by day 3 and the contrasting high mortality rate for patients still receiving MV at this time point, another multivariate analysis examined the same variables for this latter subpopulation. Three of the 5 factors listed above were retained as being significantly associated with ICU death for this subpopulation: McCabe and Jackson class 2/3, operation other than CABG alone, and persistently positive bacteremia (Table 5).

By using the Hosmer-Lemeshow statistic, no lack of fit was revealed for any of the 3 models tested.

The discriminant values, as determined by the areas under the receiver operating characteristic curves, were 0.91 (95% confidence interval [CI], 0.85-0.96) for prediction on the basis of variables available within 24 hours of ICU admission, 0.95 (95% CI, 0.90-0.99) for those available on day 3, and 0.80 (95% CI, 0.71-0.88) for the subpopulation of patients still receiving MV for 3 or more days.

The same independent variables were identified when statistical analyses were performed with the data of the

TABLE 4. Multivariate analyses of risk factors for ICU death by using variables available within 24 hours of or 3 days after ICU admission

Variable	Odds ratio (95% CI)	P value
Within 24 h of ICU admission		
Age >70 y	2.70 (1.24-5.90)	.01
Operation other than CABG alone	2.59 (1.20-5.58)	.01
McCabe and Jackson 2/3*	2.47 (1.13-5.36)	.02
APACHE II score†	1.12 (1.05-1.19)	.0005
No. of organ failures	2.07 (1.45-2.95)	.0001
Day 3 after ICU admission		
Age >70 y	3.26 (1.32-8.04)	.01
Operation other than CABG alone	3.46 (1.42-8.40)	.006
McCabe and Jackson class 2/3*	4.94 (1.98-12.33)	.0006
Persistently positive bacteremia	4.25 (1.66-10.91)	.003
MV ≥3 d	82.55 (22.15-307.61)	.0001

ICU, Intensive care unit; CI, confidence interval; CABG, coronary artery bypass grafting; MV, mechanical ventilation.

*Rapidly or ultimately fatal.¹⁷

†Score per point.

TABLE 5. Multivariate analysis of risk factors for ICU death for the subgroup of patients still mechanically ventilated 3 days after ICU admission

Variable	Odds ratio (95% CI)	P Value
McCabe and Jackson class 2/3*	6.55 (2.45-17.49)	.0002
Operation other than CABG alone	3.09 (1.23-7.75)	.01
Persistently positive bacteremia	3.54 (1.34-9.31)	.01

ICU, Intensive care unit; CI, confidence interval; CABG, coronary artery bypass grafting.

*Rapidly or ultimately fatal.¹⁷

derivation cohort. In addition, the odds ratios and 95% CIs were very close to those obtained for the entire population (data not shown). Discriminant values for the 3 previously described models applied to the validation cohort were 0.90 (95% CI, 0.80-0.99), 0.92 (95% CI, 0.83-1.00), and 0.77 (95% CI, 0.61-0.93), respectively.

Results obtained with the bootstrap procedure were very close to those reported above, confirming the validity of factors identified by using the logistic regression analyses (data not shown).

Finally, risk factors for mediastinitis-related death (n = 33 patients) retained by means of multivariate analyses were similar to those associated with ICU death (except for age and persistently positive bacteremia for the subgroup of patients still mechanically ventilated on day 3; data not shown).

It should be noted that the same independent risk factors were retained by using multivariate analyses when all candidate risk factors (ie, age, sex, McCabe class, CABG,

incubation time, APACHE II, number of organ failures, persistently positive bacteremia, and MV ≥day 3) were included in the models (data not shown).

Clinical Evolution in ICU Survivors and Nonsurvivors

MV duration (mean ± SD, median, interquartile range) was shorter for survivors than for nonsurvivors: 5.8 ± 17 days, 1 day, and 0 to 2 days versus 25.6 ± 15 days, 1 day, and 6 to 38 days ($P < .0001$). The length of ICU stay (mean ± SD, median, interquartile range) was 24.9 ± 18.8 days, 21 days, and 17 to 26 days versus 31.3 ± 29.7 days, 19 days, and 9 to 44 days, respectively ($P = .03$). The time to obtain mediastinal sterilization and duration of Redon catheter drainage did not differ significantly between survivors and nonsurvivors (mean ± SD): 8.7 ± 6.8 days versus 7.8 ± 5.1 days and 19.0 ± 5.5 days versus 18.9 ± 5.6 days, respectively. Redebriement for local failure was required by 34 (10.6%) patients: 21 (8.3%) patients among survivors and 13 (20.3%) among nonsurvivors ($P = .006$). For 22 patients, new Redon catheters were placed in the mediastinum, and the thorax was closed. The thorax was left open in 12 patients, and thereafter, the mediastinum was rapidly covered with the omental flap in 6 patients, was closed by means of rigid fixation and soft tissue reconstruction with pectoralis muscle advancement flaps in 1 patient, and was surgically closed at a later time in another patient. In the last 4 patients, no surgical closure was attempted. Two (0.8%) survivors and 3 (4.7%) nonsurvivors experienced life-threatening mediastinal hemorrhage ($P = .06$). Endocarditis was associated with mediastinitis in 21 of the 111 patients who had undergone valve replacement: 12 (18.8%) in the nonsurvivor group and 9 (3.6%) in the survivor group.

In-ICU Mortality According to Duration of MV, Underlying Disease, Cardiac Surgery, and Bacteremia

In contrast to the low mortality rate observed for patients weaned from the ventilator before day 3, among patients requiring MV for 3 days or longer after surgical debridement, the mortality rate was 20-fold higher. However, big differences in mortality rates existed in this subgroup. Thus the patients without fatal underlying disease who had undergone CABG alone and who did not experience persistently positive bacteremia had a mortality rate of 21.4%. On the other hand, among the patients who had undergone surgical intervention other than CABG alone and who experienced sustained bacteremia, this percentage reached 89% for patients also experiencing an ultimately or rapidly fatal underlying disease (McCabe and Jackson class 2/3).

Discussion

This study analyzed the largest cohort to date of adults with acute poststernotomy mediastinitis. All 316 patients had been treated with the same surgical approach without any modification during a 10-year period, associating urgent

debridement and closed-drainage aspiration with Redon catheters. Five independent factors available within the first 24 hours after ICU admission were associated with in-ICU mortality. When parameters known as of day 3 in the ICU were analyzed, 2 other major factors were identified: persistently positive bacteremia and MV for 3 days or longer. The mortality rate was extremely low, around 2%, for patients who had been rapidly weaned off the ventilator. In contrast, the mortality rate exceeded 50% for patients requiring 3 or more days of MV. For this subset, a dismal outcome was observed when 3 other factors (McCabe and Jackson class 2/3, persistently positive bacteremia, and non-CABG operations) were present.

Mediastinal infection is still a dreadful complication with a high mortality rate, ranging between 5% and 47%.^{6,11-13,21-24} Mortality rates reported in large series of patients were around 20%.¹³ Other authors described lower mortality rates.^{3,4,9,15,25} However, these series included patients with sterile sternal dehiscence^{4,25} and patients without signs of severity. For example, in one of these recent reports, 30.6% of the patients did not require ICU transfer.¹² It should also be noted that other authors included patients with very long incubation times and with local treatment problems but without systemic complications.

Because our unique referral pattern was mediastinitis serious enough to require ICU treatment, comparison with other studies dealing with prognostic factors of patients with poststernotomy mediastinitis is not easy.^{3,11,12} Nevertheless, some similar factors associated with bad outcome emerged from those series. Septicemia was associated with mortality of patients treated with muscle-flap coverage.³ Older age was also associated with treatment failure in the study of Kirsch and associates.¹² Conversely, *S aureus* methicillin resistance was not associated with fatal outcome in our multivariate analysis. The absence of a statistical link between methicillin resistance and mortality in various clinical situations has been reported by others.²⁶⁻²⁸

Nonetheless, our study design provides several advantages compared with previous observational investigations. First, our cohort was large. Second, these were consecutive patients treated in a single center with the same management protocol concerning both the first-line surgical approach and antibiotic regimen. Moreover, the mortality rate was stable from one year to another. Third, clinical and biologic parameters were routinely recorded prospectively for these patients. Fourth, our study used a time-honored comorbidity index to analyze the effect of underlying disease on the risk of death,¹⁷ a validated acute disease severity score,¹⁸ and clinical and biologic characteristics explicitly defined and easily identifiable by the physician at the bedside. Finally, the same independent factors were identified when we randomly selected 65% of the population to con-

stitute a derivation data set, and the concordance indexes were good when we tested the models in a distinct validation cohort or when we used a bootstrapping method.

The present study also confirms that a first-line approach with closed-drainage aspiration with Redon catheters achieves excellent results, with low morbidity and low mortality rates in the absence of severe systemic factors. In our current practice, 99% of patients with mediastinitis within 30 days after cardiac surgery are treated with the Redon catheter technique, which is not applicable only in the case of massive sternal necrosis, skin necrosis, or both. In the case of patent first-line treatment failure, surgical redebridement is performed, and new Redon catheters are repositioned in the mediastinum. When tissue necrosis does not permit wound closure, open wound packing is applied temporarily, and one of the plastic surgery techniques is used soon afterward to close the mediastinum.

However, our study has some limitations. First, we cannot precisely determine the number of cases of cardiac surgery and the frequency of deep sternal wound infections during this 10-year period because patients were addressed from 7 different centers. Second, this was a retrospective study, even though data were recorded prospectively. Third, we did not classify mediastinal infections according to the system proposed by El Oakley and Wright⁷ because many of our patients were treated in our ICU before its publication. Fourth, our study design differs markedly from those of other studies dealing with prognostic factors. In particular, our very simple database did not include factors associated with the occurrence of mediastinitis, such as preoperative (eg, diabetes mellitus) and perioperative (eg, use of both internal thoracic arteries, use of an intra-aortic balloon pump, perioperative myocardial infarction, and surgical duration) variables. We cannot exclude that these variables might have been associated with death in the ICU if tested in our multivariate models. However, it should be noted that none of these factors were associated with fatal outcome in previous studies and that the most relevant factors of poststernotomy mediastinitis outcomes might be those evaluated at the onset of the infection. Finally, the absence of systematic follow-up with respect to further infection or mortality is another limitation of the present study.

In conclusion, this study provides a set of simple variables strongly associated with ICU death for patients with acute poststernotomy mediastinitis requiring initial ICU care and managed by means of debridement and closed-drainage aspiration with Redon catheters. These variables are linked to patients' underlying disease, severity of the infection at ICU admission, and type of initial cardiac operation. Reassessment of patient characteristics on day 3 permits an update of the probability of ICU death. Importantly, the ICU mortality rate was very high for patients with rapidly or ultimately fatal underlying disease or diseases

who had undergone cardiac surgery other than CABG alone, who experienced persistently positive bacteremia, and who were still mechanically ventilated on day 3.

Conversely, patients weaned off the ventilator within 3 days after debridement had a low mortality rate (around 2%), regardless of the association with other ICU mortality risk factors.

References

1. Sarr MG, Gott VL, Townsend TR. Mediastinal infection after sternotomy. *Ann Thorac Surg.* 1984;38:415-23.
2. Trouillet JL, Chastre J, Fagon JY, Pierre J, Domart Y, Gibert C. Use of granulated sugar in treatment of open mediastinitis after cardiac surgery. *Lancet.* 1985;2:180-4.
3. Jones G, Jurkiewicz M, Bostwick J, Wood R, Trimble Bried J, Culbertson J, et al. Management of the infected median sternotomy wound with muscle flaps. *Ann Surg.* 1997;225:766-78.
4. Durandy Y, Batisse A, Bourel P, Dibie A, Lemoine G, Lecompte Y. Mediastinal infection after cardiac operation. A simple closed technique. *J Thorac Cardiovasc Surg.* 1989;97:282-5.
5. Calvat S, Trouillet JL, Nataf P, Vuagnat A, Chastre J, Gibert C. Closed drainage using Redon catheters for local treatment of poststernotomy mediastinitis. *Ann Thorac Surg.* 1996;61:195-201.
6. Berg HF, Brands WG, van Geldorp TR, Kluytmans-Vandenbergh FQ, Kluytmans JA. Comparison between closed drainage techniques for the treatment of postoperative mediastinitis. *Ann Thorac Surg.* 2000;70:924-9.
7. El Oakley R, Wright J. Postoperative mediastinitis: classification and management. *Ann Thorac Surg.* 1996;61:1030-6.
8. L'Ecuyer PB, Murphy D, Little JR, Fraser VJ. The epidemiology of chest and leg wound infection following cardiothoracic surgery. *Clin Infect Dis.* 1996;22:424-9.
9. Borger M, Rao V, Weisel R, Ivanov J, Cohen G, Scully H, et al. Deep sternal wound infection: risk factors and outcomes. *Ann Thorac Surg.* 1998;65:1050-6.
10. The Parisian Mediastinitis Study Group. Risk factors for deep sternal wound infection after sternotomy: a prospective, multicenter study. *J Thorac Cardiovasc Surg.* 1996;111:1200-7.
11. De Feo M, Renzulli A, Ismeno G, Gregorio R, Della Corte A, Utili R, et al. Variables predicting adverse outcome in patients with deep sternal wound infection. *Ann Thorac Surg.* 2001;71:324-31.
12. Kirsch M, Mekontso-Dessap A, Houël R, Giroud E, Hillion ML, Loisanse D. Closed drainage using Redon catheters for sternotomy mediastinitis: results and risk factors for adverse outcome. *Ann Thorac Surg.* 2001;71:1580-6.
13. Krabatsch T, Hetzer R. Poststernotomy mediastinitis treated by transposition of the greater omentum. *J Card Surg.* 1995;10:637-43.
14. Rand RP, Cochran RP, Aziz S, Hofer BO, Allen MD, Verrier ED, et al. Prospective trial of catheter irrigation and muscle flaps for sternal wound infection. *Ann Thorac Surg.* 1998;65:1046-9.
15. Milano C, Georgiade G, Muhlbaier L, Smith P, Wolfe W. Comparison of omental and pectoralis flaps for poststernotomy mediastinitis. *Ann Thorac Surg.* 1999;67:377-81.
16. Song DH, Wu LC, Lohman RF, Gottlieb LJ, Franczyk M. Vacuum assisted closure for the treatment of sternal wounds: the bridge between debridement and definitive closure. *Plast Reconstr Surg.* 2003;111:92-7.
17. McCabe WR, Jackson GG. Gram-negative bacteremia. *Arch Intern Med.* 1962;110:847-64.
18. Knaus WA, Drapper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. *Crit Care Med.* 1985;13:818-29.
19. Fagon JY, Chastre J, Novara A, Medioni P, Gibert C. Characterization of intensive care unit patients using a model based on the presence or absence of organ dysfunctions and/or infection: the ODIN model. *Intensive Care Med.* 1993;19:137-44.
20. Kollef MH, Wragge T, Pasque C. Determinants of mortality and multiorgan dysfunction in cardiac surgery patients requiring prolonged mechanical ventilation. *Chest.* 1995;107:1395-401.
21. Ottino G, De Paulis R, Pansini S, Rocca G, Tallone MV, Comoglio C, et al. Major sternal wound infection after open-heart surgery: a multivariate analysis of risk factors in 2,579 consecutive operative procedures. *Ann Thorac Surg.* 1987;44:173-9.
22. Grossi EA, Esposito R, Harris LJ, Crooke GA, Galloway AC, Colvin SB, et al. Sternal wound infections and use of internal mammary artery grafts. *J Thorac Cardiovasc Surg.* 1991;102:342-7.
23. Bitkover CY, Gardlund B. Mediastinitis after cardiovascular operations: a case-control study for risk factors. *Ann Thorac Surg.* 1998;65:36-40.
24. Newman LS, Szczukowski LC, Bain RP, Perlino CA. Suppurative mediastinitis after open-heart surgery. A case-control study of risk factors. *Chest.* 1988;94:546-53.
25. El Gamel A, Yonan NA, Hassan R, Jones MT, Campbell CS, Deiraniya AK, et al. Treatment of mediastinitis: early modified Robicsek closure and pectoralis major advancement flaps. *Ann Thorac Surg.* 1998;65:41-7.
26. Lewis E, Saravolatz LD. Comparison of methicillin-resistant and methicillin-sensitive *Staphylococcus aureus* bacteremia. *Am J Infect Control.* 1985;13:109-14.
27. Hershov RC, Khayr WF, Smith NL. A comparison of clinical virulence of nosocomially acquired methicillin-resistant and methicillin-sensitive *Staphylococcus aureus* infections in a university hospital. *Infect Control Hosp Epidemiol.* 1992;13:587-93.
28. Mylotte JM, Tayara A. *Staphylococcus aureus* bacteremia: predictors 30-day mortality in a large cohort. *Clin Infect Dis.* 2000;31:1170-4.