Influence of sternal size and inadvertent paramedian sternotomy on stability of the closure site: A clinical and mechanical study

J. Zeitani, MD, PhD,a A. Penta de Peppo, MD,b M. Moscarelli, MD,a L. Guerrieri Wolf, MD,a A. Scafuri, MD,a P. Nardi, MD,a F. Nanni, PhD,c E. Di Marzio, MD,d P. De Vico, MD,d and L. Chiariello, MDa

Background: The influence of sternal size and of inadvertent paramedian sternotomy on stability of the closure site is not well defined.

Methods: Data on 171 consecutive patients undergoing cardiac surgery through a midline sternotomy were prospectively collected. Intraoperative measurements of sternal dimension included thickness and width at the manubrium, the third and fifth intercostal spaces; paramedian sternotomy was defined as width of one side of the sternum equaling 75% or more of the entire width, at any of the three levels. The chest was closed with simple peristernal steel wires and inspected to detect deep wound infection and/or instability for 3 postoperative months. The sternal factors and several patient/surgery–related factors were included in a multivariate analysis model to identify factors affecting stability. An electromechanical traction test was conducted on 6 rewired sternal models after midline or paramedian sternotomy and separation data were analyzed.

Results: Chest instability was detected in 12 (7%) patients and wound infection in 2 (1.2%). Patient weight (P = .03), depressed left ventricular function (P = .04), sternum thickness (indexed to body weight, P = .03), and paramedian sternotomy (P = .0001) were risk factors of postoperative instability; paramedian sternotomy was the only independent predictor (P = .001). The electromechanical test showed more lateral displacement of the two rewired sternal halves after paramedian than midline sternotomy (P = .002); accordingly, load at fracture point was lower after paramedian sternotomy (220 ± 20 N vs 545 ± 25 N, P = .001).

Conclusions: Inadvertent paramedian sternomoty strongly affects postoperative chest wound stability independently from sternal size, requiring prompt reinforcement of chest closure.

Midline sternotomy, introduced by Julian and associates1 in 1957, is the preferred access for operations on the heart and great vessels, allowing good surgical exposure and rapid postoperative wound healing. Nevertheless, wound complications may occur, particularly in patients with concomitant pathologic conditions affecting wound healing, such as chronic obstructive pulmonary disease, diabetes, obesity, or peripheral arterial disease, or after extensive sternal devascularization owing to bilateral internal thoracic artery harvesting.2–8 Deep wound dehiscence and consequent instability of the chest closure undoubtedly represents the most feared complication, facilitating tissue infection and mediastinitis.9,10 Reinforcement of the chest closure, as proposed with different techniques by Robicsek, Daugherty, and Cook11 and by other authors,12,13 may prevent postoperative dehiscence in patients at high risk of wound complications; also, titanium plates,14 stainless steel coils, or cables15,16 have been proposed in substitution of simple steel wires and have been tested to improve postoperative sternal stability.
Indeed, routine application of time-consuming techniques and/or costly materials depends on the precise identification of patients who would clearly benefit from reinforcement of the chest closure. Despite the numerous reports on several risk factors of wound complications, the influence of sternum-related variables in comparison with the other factors has been poorly investigated. The purpose of this study was to analyze the impact of size of the sternum and inadvertent performance of a paramedian sternotomy on stability of the closure site.

Methods

From June 2004 to November 2004, data on 171 consecutive patients undergoing median sternotomy for coronary artery bypass grafting (n = 99) or valve replacement (n = 72) at our institution were prospectively collected. Also, a laboratory electromechanical test was conducted on 6 artificial sternum models formed from 20 lb/ft3–density polyurethane foam (Pacific Research Labs, Inc, Vashon Island, Wash), a material that has been characterized as a model for human cancellous bone and used to construct sternum models, which have been validated for studies of sternal measurements and are widely adopted in electromechanical studies. The models were longitudinally divided at the midline (n = 3) or at the paramedian (75% asymmetrical) line (n = 3) with an oscillating saw, rewired by a cardiothoracic surgeon with 5 peristernal No. 5 steel wires (AE Medical Corporation, Farmingdale, NJ) placed in simple interrupted fashion, and then mounted onto an electromechanical testing system (model 8055; Instron Corp, Canton, Mass) (Figure 1). In particular, 6 lateral anchoring holes were made in each side of the sterna, 5 at the costal junctions and 1 in the manubrium, and lateral distraction forces were applied through pairs of steel cables secured across the holes through small metal hoses. Three strain gauges ( Vishay Intertecnicology Inc, Malvern, Pa) were applied over the closure line on the posterior surface of the manubrium, midsternum (at the third intercostal space), and xiphoid, and separation of the two sternal halves was measured with a Spider 8 apparatus in half bridge configuration (HBM, Marlborough, Mass) during a continuously increasing tensile test at 2 mm/min, to generate a load-displacement curve until the construct would break.

Statistical Analysis

Influence of variables on stability of the closure site was assessed by the unpaired Student t test, the χ2 test, or the Fisher exact test, as appropriate. Sternal-related risk factors included sternal width and thickness at the three sternal levels, the mean individual patient width and thickness, and occurrence of inadvertent paramedian sternotomy. Other patient- and surgery-related factors included age, sex, New York Heart Association functional class.
III-IV, patient weight as a continuous variable and as weight greater than 80 kg, obesity (body mass index ≥ 30 kg/m²), echocardiographic left ventricular ejection fraction lower than 50%, diabetes mellitus, chronic obstructive pulmonary disease, peripheral vascular disease, renal failure (serum creatinine value > 1.5 mg/dL), type of surgical procedure (bypass grafting or valve replacement), resident or attending surgeon, bilateral internal thoracic artery harvesting, time of cardiopulmonary bypass, postoperative use of inotropic drugs during the intensive care stay, reopening for bleeding, and transfusion of blood units. Factors independent of the other variables (P < .05) were included in a stepwise logistic regression prediction model.

Separation data of the electromechanical test were compared by 2-way repeated-measures analysis of variance to detect influence of type of sternotomy and increasing loads on lateral displacement of sternal halves. Ultimate load values at the time of fracture of the sternal models were compared by the unpaired Student’s t test. Variables are presented as mean ± 1 standard deviation. Statistical analysis was done by the SPSS statistical software package (SPSS Inc, Chicago, IL).

### Results

No hospital mortality occurred. Instability of the chest closure was detected in 12 (7%) patients; wound infection was diagnosed in 2 (1.2%) patients. Surgical treatment included chest reopening, debridement of necrotic tissue, rewiring of the sternum according to the Robicsek method in 3 patients or with plain steel wires in 5 patients, or sternal reapproximation by use of bilateral “pectoralis major” muscle flaps in 4 patients; primary closure of subcutaneous and skin layers was then accomplished by absorbable sutures, as previously reported in patients with superficial wound dehiscence, and wide-spectrum intravenous antibiotic therapy was instituted. All patients recovered completely. At univariate analysis, significant predictors of instability included patient body weight (P = .03), body weight greater than 80 kg (P = .03), preoperative depressed left ventricular function (P = .04), the mean individual sternal thickness indexed to patient’s body weight (P = .03), and inadvertent paramedian sternotomy (P = .0001); no other measurement of sternal size was related to wound instability (Tables 1 and 2). At multivariate analysis, the paramedian sternotomy was the only risk factor affecting stability of the closure site, independently of the other variables (P = .001, odds ratio 11.4, 95% confidence limits 2.5-51.7). All surgeons were right-handed: paramedian sternotomy occurred to the right in 11 (69%) and to the left in 5 (31%) patients; correlation of the paramedian incision with the side on which the internal thoracic artery was mobilized did not increase the chance of wound instability, which occurred in 2 of 6 (33%) patients with correlation and in 4 of 10 (40%) of the other patients. No patient- or surgeon-related factor influencing occurrence of the off-center incision could be identified, including patient sex (P = .67), weight (P = .32), obesity (P = .18), sternal width (P = .16) and thickness (P = .81), or resident or attending surgeon (P = .27).

All traction tests were interrupted for transverse fracture of one of the two halves of the rewired sternal models, at the sternoxiphoid junction in 5 and the lower third in 1; breakage of the construct occurred after steel wires cut through the casts for a variable extent. Ultimate load values inducing fracture were lower after paramedian sternotomy (220 ± 20 N vs 545 ± 25 N, P = .001). Lateral displacement at 200 N tensile force (shortly before fracture) after median or paramedian sternotomy was 9.5 ± 0.4 versus 11.2 ± 0.8 mm at the xiphoid (P = .016), 1.5 ± 0.3 versus 2.7 ± 0.4 mm at the midsternum (P = .008), and 3.8 ± 0.6 versus 4.7

### Table 2. Sternal-related variables in patients with and without postoperative instability of the chest closure site

<table>
<thead>
<tr>
<th>Variable</th>
<th>Instability (n = 12)</th>
<th>Stability (n = 159)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sternum width, mean (mm)</td>
<td>36.1 ± 6.5</td>
<td>32.9 ± 5.8</td>
<td>.09</td>
</tr>
<tr>
<td>Sternum width/body weight (mm/kg)</td>
<td>0.43 ± 0.07</td>
<td>0.46 ± 0.11</td>
<td>.49</td>
</tr>
<tr>
<td>Sternum thickness, mean (mm)</td>
<td>10.8 ± 1.4</td>
<td>11.2 ± 2.2</td>
<td>.48</td>
</tr>
<tr>
<td>Sternum thickness/body weight (mm/kg)</td>
<td>0.13 ± 0.03</td>
<td>0.16 ± 0.03</td>
<td>.03</td>
</tr>
<tr>
<td>Paramedian sternotomy</td>
<td>6 (50%)</td>
<td>10 (6.2%)</td>
<td>.0001</td>
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</table>
The impact of the anatomic characteristics of the sternum on wound complications has been poorly investigated; also, the precise influence of inadvertent paramedian sternotomy, a technical drawback of longitudinal chest opening, has not been well defined in comparison with other known risk factors of wound complications. We hypothesized that a better knowledge of these aspects might also help to clearly identify those patients who would benefit from routine application of a reinforcement technique of chest closure. Indeed, the various techniques and materials for sternum reinforcement are somewhat time-consuming and more expensive than the usual closure with simple wires, and surgeons may hesitate to adopt routinely one of these techniques in all categories of patients at risk.

We found that sternal size did not independently affect chest wound stability; in fact, sternal thickness affected postoperative stability if indexed to the patient’s body weight, which is a widely known risk factor for wound complications. That finding is presumably related to the great variability of sternal width and thickness that is normal between patients. We found, instead, that inadvertent performance of paramedian sternotomy strongly affected postoperative stability at the closure site, as also suggested previously. As expected, other known risk factors of deep wound dehiscence were identified, such as patient weight and depressed left ventricular function. Interestingly, at multivariate comparisons, paramedian sternotomy was the most powerful risk factor of postoperative chest instability, suggesting that this technical drawback might be as important as or more important than other already widely known risk factors; of note, that influence occurred independently of sternal size and the other analyzed variables. That finding was enhanced by the observations at the electromechanical test on the rewired sternal models, showing more separation of the two sternal halves during lateral traction and a consistently lower ultimate load inducing the model break after paramedian than midline sternotomy. As already shown in previous reports, the higher lateral displacement was detected at the xiphoid.

These findings have practical implications on the intraoperative choice of the method of chest closure; indeed, occurrence of inadvertent paramedian sternotomy is easily identified by inspection at the time of chest opening and may therefore promptly suggest reinforcement of chest closure by use of one of the proposed methods. Imperfect sternal opening may not simply depend on surgical skill and experience; for instance, we found the same impact of residents versus attending surgeons on the occurrence of sternal instability, as already reported by others. Also, precise sawing at the midline may easily be compromised if the outer sternal border is hardly detectable, as in overweight patients, or when the bone is narrow; nonetheless, patients significantly at risk for a paramedian incision could not be identified in the present study.

In conclusion, occurrence of inadvertent paramedian sternotomy, independently of sternal size or other factors,
appears highly significant among factors jeopardizing a successful chest closure and may promptly induce surgeons to routine application of a sternal reinforcement technique.

References