Control of Separation in Sternal Instability by Supportive Devices: A Comparison of an Adjustable Fastening Brace, Compression Garment, and Sports Tape

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Objective: To evaluate the effectiveness of 3 supportive devices in controlling sternal separation.

Design: A cross-sectional, randomized intervention study.

Setting: Participants were from the general community who were referred to the study by their cardiac surgeon or cardiologist.

Participants: Fifteen patients (12 men, 3 women) between 49 and 80 years of age with sternal instability after a median sternotomy.

Interventions: Not applicable.

Main Outcome Measures: Support from sports tape, a compression garment, and an adjustable fastening brace was assessed by an ultrasound-based measure of sternal separation contingent on movement and by self-report measures of comfort, pain, feeling of support, ease of upper-limb movement, and ease of breathing.

Results: For both sternal separation and self-report data, some support was better than no support, and a supportive device worn on the body was better than sports tape. Wearing an adjustable fastening brace was better than a compression garment and, compared with no support, closed the sternal gap by 20% or 2.7mm (95% confidence interval, 1.5–3.9mm). The effects of wearing the different supportive devices on visual analog scale ratings of comfort, pain, support, ease of breathing, and movement mirrored the results obtained for sternal separation, thus providing agreement between self-report and objective measures.

Conclusions: Supportive devices may be useful in the management of patients with sternal instability because wearing one resulted in a reduction of both sternal separation and pain report after movement. The largest effect was obtained from wearing an adjustable fastening brace.

Key Words: Doppler ultrasound; Postoperative care; Postoperative complications; Rehabilitation; Surgery.

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The sternotomy incision performed along the vertical midline of the sternum for many cardiothoracic operative procedures remains popular as it provides the best access to the heart and surrounding structures.1-7 In the majority of patients, the sternum heals with no major complications; however, infection, mediastinitis, and sternal nonunion or instability do occur in a significant number of cases. Sternal wound complications have been reported to increase the length of hospitalization and significantly influence readmission rates, utilization of hospital resources, and cost of care more consistently than any other complication after cardiac surgery.8-12

Over the last 2 decades, the incidence of sternal instability has remained essentially unchanged at between 1% and 16%.5,7,13 This may be because of the difficulty in wiring and fixating the sternum after it has been separated because it forms part of a bony platform that supports ventilation as well as motion of the upper limbs and trunk.5,7,13 The term sternal instability is applied in the literature to describe abnormal motion of the sternum caused by either fracture or disruption of the sternal wires inserted to reunite the surgically divided sternum.6

The separation of the 2 sternal halves may be total, involving the entire sternum, or partial, being limited to a portion of the sternum, usually the caudal third because of its lesser blood supply.14,16 Sternal instability is characterized by sternal clicking, excessive motion with resultant pain, discomfort, and difficulty performing activities of daily living.5,7,13

Risk factors that have been associated with sternal instability include diabetes, prolonged mechanical ventilation (>48h), obesity, smoking, osteoporosis, bilateral internal mammary artery grafting, large breast size, the use of β-adrenergic medications, and the presence of a chronic respiratory disease.1,4,14,17,18

During the acute postoperative period, the excessive motion at the sternotomy site can result in pain and discomfort and may be followed by atelectasis and pneumonia secondary to a decreased inspiratory effort.10 Although many patients can be successfully treated with sternal debridement and rewiring and others with muscle flap reconstructions, some do not have the option of further surgical repair because of an increased mortality risk accompanied by little guarantee of better functional outcomes. Long-term follow-up studies12,19 have reported that between 42% and 45% of patients with initial sternal instability complain of chronic sternal instability after surgical repair.

Although there are studies that have reported the existence of poststernotomy chest pain and neuropathy of the upper limb at rates ranging from 28% to 78% in patients 6 months to 12 years after cardiac surgery, such epidemiologic studies on patients with sternal instability are scarce.7,20,21

Furthermore, to date, there are no clinical guidelines for the conservative care and management of patients with sternal instability after cardiac surgery. A small number of patients on long-term follow-up have reported that their symptoms were not severe enough to warrant further evaluation.12

List of Abbreviations

ANOVA analysis of variance

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instability. In an attempt to attain some sternal closure and
stability and reduce pain postoperatively, patients are often
instructed by staff to support their sternum with a pillow,
especially when performing respiratory techniques such as
coughing or when carrying out transfers from a chair to bed.
Following the same logic, there are supportive devices avail-
able that have been reportedly designed to reduce sternal pain,
prevent wound breakdown and sternal instability. The support
is either taped to the skin, applies elastic compressive support
to the region through a worn garment, or exerts restraint
through an adjustable fastening system on a brace or jacket.
The rationale for the use of these devices is that they provide
circumferential support and resistance to increases in intra-
thoracic pressure that may result in distractive forces on the
sternum during activities of daily living. They may also act
to complement the parasternal muscles (intercostals, sternalis,
transverse thoracis) and muscles of the anterior abdominal
wall, which are thought to play a role in the stabilization of
the thoracic cage. In the single reported clinical trial of 1
device, the Heart Hugger, it was noted that 9 of 12 patients
reported a reduction of pain (mean, 4.4 points on a 10-point
scale), and most found it helpful when coughing. A U.S.
Federal Device Authority investigation of the Heart Hugger
conducted at 3 cardiothoracic centers (n = 30; mean age, 60.2y;
reported that 87% (n = 26) of cardiac surgery patients also
reported a significant reduction in postoperative pain with its
use. However, to date, no studies have examined the mechan-
cal or subjective effects of supportive devices in patients with
sternal instability. In addition, there is no information about the
compression forces exerted by these devices.

In previous research, ultrasonography has been found to be
a reliable and noninvasive means of quantifying sternal sepa-
ration in individuals with sternal instability (intraclass correla-
tion coefficient, model 2,1, range, .90–.93). In addition, the
greatest difference between the ultrasound and vernier mea-
sures was noted to be 1.2 mm, thereby establishing good valid-
ity for the measure. As such, separation measurements taken
by ultrasound may objectively reflect the extent of bony sep-
paration occurring in patients experiencing sternal instability.
Accordingly, the aim of this study was to measure the effects
of a variety of supportive devices in terms of their effects on
sternal separation as measured by ultrasound and by the re-
ported symptoms in patients with sternal instability. Specifi-
cally, the primary hypothesis was that incremental degrees of
restraint from supportive devices would be associated with a
successive reduction in the amount of separation at the sternal
edges. The secondary hypotheses related to the effects of
various task conditions on sternal separation. It was also hy-
pothesized that the results from self-report measures would
parallel those of sternal separation.

METHODS

Fifteen subjects (12 men, 3 women) with sternal instability
more than 8 weeks postonset were recruited for the study after
an advertisement was placed in the physiotherapy practice of
the second author and a written medical referral from the
respective cardiac surgeon or cardiologist. Each subject was
also asked to report on whether he/she currently required
medications for the management of his/her chest pain more
than 3 days a week. Medications were classified under the
following headings: paracetamol, paracetamol and codeine,
nonsteroidal anti-inflammatory, or opiates (table 1).

People were included if they scored 2 or more on the Sternal
Instability Scale after a physical examination by a cardiac
surgeon and physiotherapist. The Sternal Instability Scale is a
manual test that reliably rates sternal separation from 0
(stable with no detectable motion) to 3 (completely separated
sternum with marked increase in motion) (table 2). People
were excluded if they had a medical condition or shoulder
injury that would preclude them from participating in the study
or if they had undergone surgical rewiring of their unstable
sternum. Discomfort, crepitus, and an unstable feeling or ex-
cessive motion that interfered with their level of function or
comfort were reported by all subjects. Written informed con-
sent was obtained from each participant before the commence-
ment of the study. Approval for conducting the study was
obtained from the Human Research Ethics Committee of the
University of Sydney.

Intervention: Supportive Devices

Each subject attended an individual session in which they
were first asked to pick a labeled slip of paper from an envelope
to determine the order of the allocation of interventions. Sub-
jects were briefed at the commencement of the session, and
initial measures were made. Three modes of intervention
(sports tape, compression garment, an adjustable fastening
brace) and a no-intervention control condition were assessed.

The sports tape application included a porous, hypoallerg-
ic tape of 10 cm in width and rigid sports tape of 10 cm in
width. Two lengths of hypoallergenic tape were initially applied parallel to the sternum from the sternoclevic-
ular joints to a point 1 cm below the xiphisternum. Two strips
were also placed diagonally over the top of these bands, pass-
ing from the inferior border of each clavicle to the level of 1 cm
below the xiphisternum. These strips were then reinforced by 2
additional elastoplast layers placed vertically and diagonally.

The compression garment consisted of an elasticized tubu-
lar bandage with an inner layer of polyurethane foam and a
central self-adhesive (Velcro) band for ease of application (fig
1B). It was 30 cm in length and available in small, medium,
and large widths. The garment is a single-use device that is applied
across the chest wall and secured by self-adhesive at the
midline, as shown in figure 1B.

The adjustable fastening brace used was an elasticized
single-use supportive device with integrated cough handles to
provide additional support (eg, during coughing, transfers) (fig
1C). This brace is adjustable and has 2 shoulder straps to secure
it in place. It is available in varying sizes ranging from small
(93–99 cm) to XXXLarge (135–144 cm) and is an example of a
patient-activated support harness similar in design to the Heart
Hugger.

Each subject was fitted and sized for the compression gar-
ment and fastening brace by the chief investigator. Each inter-
vention was applied for 30 minutes before data collection to
allow the subjects time to accommodate to the device. There
was a rest period of 10 minutes between interventions.

Measurement. The clinical ultrasound unit used in the
study was a Dornier MedTech MicronVision Ultrasound with
the following specifications: intensity of 5 to 7 MHz, a depth of
3 cm, gain of 15, and smoothing setting of 2. The region of
greatest instability along the sternum for each subject was
identified by the chief investigator using the Sternal Instability
Scale and marked on the skin as a reference point for all
measurements. The amount of separation in millimeters at
different vertical points on the sternum was measured from the
projected image by the chief investigator who was experienced
in ultrasonography, and the measures were entered on individual
subject data sheets by a person independent of the study (fig 2).
This allowed the obscuring of consecutive measures for each
subject from the chief investigator.

The aim was to evaluate the effects of exercises on sternal
separation while wearing the supportive devices. A series of

Controlling Sternal Instability with Supportive Devices, El-Ansary

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<table>
<thead>
<tr>
<th>Subject</th>
<th>Age (y)</th>
<th>Sex</th>
<th>Type of Surgery</th>
<th>Pain (VAS)</th>
<th>Time Since Surgery</th>
<th>Problems Before Surgery</th>
<th>Risk Factors to Wound Healing</th>
<th>Current SIS Score</th>
<th>Postoperative Events</th>
<th>Current Medications for Pain</th>
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<tr>
<td>1</td>
<td>65</td>
<td>M</td>
<td>AVR</td>
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<td>6mo</td>
<td>HT, back pain, sinusitis</td>
<td>Beta-adrenergic medications</td>
<td>3</td>
<td>Dry cough</td>
<td>NSAIDs</td>
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<td>M</td>
<td>CABG</td>
<td>4</td>
<td>8mo</td>
<td>None</td>
<td>Obese</td>
<td>3</td>
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<td>70</td>
<td>F</td>
<td>CABG</td>
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<td>10y</td>
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<td>Obese, diabetes, beta-adrenergic medications, osteoporosis, post menopause, breast size, COPD</td>
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<td>CABG</td>
<td>5</td>
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<td>4</td>
<td>4y</td>
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<td>Obese, diabetes</td>
<td>3</td>
<td>Chest infection</td>
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<td>CABG</td>
<td>3</td>
<td>2y</td>
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<td>Obese, diabetes renal failure</td>
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<td>HT, OA</td>
<td>Obese</td>
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<td>3mo</td>
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<td>3</td>
<td>Chest infection, mediastinitis</td>
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<td>68</td>
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<td>CABG</td>
<td>6</td>
<td>4mo</td>
<td>HT</td>
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<td>Paracetamol</td>
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<tr>
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<td>CABG</td>
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<td>1mo</td>
<td>HT</td>
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<td>Right pleural effusion</td>
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<td>4</td>
<td>3mo</td>
<td>HT</td>
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<td>3</td>
<td>Mediastinitis</td>
<td>Opiate</td>
</tr>
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<td>62</td>
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<td>CABG, AVR</td>
<td>6</td>
<td>4mo</td>
<td>HT</td>
<td>Obese, breast size, post menopause</td>
<td>2</td>
<td>None</td>
<td>Paracetamol, paracetamol and codeine</td>
</tr>
</tbody>
</table>

Abbreviations: AF, atrial fibrillation; AVR, aortic valve replacement; CABG, coronary artery bypass graft; COPD, chronic obstructive pulmonary disease; F, female; HT, hypertension; M, male; MI, myocardial infarction; NSAIDs, nonsteroidal anti-inflammatory drugs; OA, osteoarthritis; SIS, Sternal Instability Scale; VAS, visual analog scale.
upper-limb movements were examined, with each participant in a supported seated position. These reflected the routine active range of shoulder motion exercises used by physiotherapists for patients after cardiac surgery. Thus, measures were taken during arms at rest (0°), arm elevation midrange (90°), and at the end of the elevation range (180°). Other movement conditions measured were unilateral arm elevation without a weight, unilateral arm elevation with a weight, bilateral arm elevation without a weight, and bilateral arm elevation with a weight. A 1-kg weight was selected because it is commonly used in cardiac rehabilitation settings and is a standard packaging weight for grocery items. In addition, 2 functional tasks, pushing up from a chair and flexion at the elbow against an elasticized length of rubber with a low to moderate resistance (green Theraband®), were performed unilaterally and bilaterally.

Patient self-report. Ratings of comfort, pain, feeling of support, ease of upper-limb movement, and ease of breathing were obtained in the rest period after the exercises with each mode of intervention. These ratings were made on a 100-mm visual analog scale with the numbers 1 to 10 spaced evenly along the line. The extremes of the scales were labeled low on the left and high on the right. Subjects scored themselves after task performance by circling a number or marking the line.

Data Analysis

Sternal separation data were obtained at rest, midway, and at the end of the 2 functional tasks (elbow flexion, chair push-up) when performed unilaterally and bilaterally and under all 4 support conditions. Analysis was performed by using repeated-measures ANOVA in the general linear model procedure of SPSS® for Windows. Contrasts were used to assess the effects of adding features incrementally to the supportive devices. The Helmert contrast option was used with the factor type of support to generate orthogonal tests across the no-support, sports tape, compression garment, and fastening brace conditions that compared each successive level with the mean of the later levels.

In addition, the sternal separation measures obtained when either 1 or both arms were elevated; loaded or unloaded; at rest, at midrange, or at end-range overhead; and with all 4 support conditions were analyzed in a 2 × 2 × 3 × 4 repeated-measures ANOVA. Helmert contrasts were again used for examining the effects of type of support across arm-elevation conditions.

Scores from each participant from the 5 patient self-report scales were examined in repeated-measures ANOVA, with the same procedure used to examine any cumulative effect of the addition of features.

RESULTS

Subject characteristics and demographics are included in Table 1.

Sternal Separation

The mean values for sternal separation measured during performance of the functional tasks and during arm elevation under each of the 4 support conditions are given in Table 3.
Sternal separation during 2 functional tasks: elbow flexion against Theraband resistance, and pushing up from a chair. The overall test of the support factor showed that there were significant differences in sternal separation associated with different kinds of support devices (P<.001). Because the Mauchly sphericity test associated with this factor was significant (P=.004), the Greenhouse-Geisser correction to degrees of freedom was adopted without any change to the obtained level of significance. Having some support resulted in a mean sternal separation of 12.1mm, whereas having no support during the performance of these tasks resulted in a larger mean separation of 14mm; the first contrast showed that this difference was significant (F1,14=17.3, P=.001). When sports tape was compared with the 2 devices that are worn (compression garment, fastening brace), the 2 devices that are worn showed a lesser separation, by 1.8mm (F1,14=19, P=.001). Finally, when the compression garment and the fastening brace were compared, the 1.2-mm smaller mean sternal separation measured during task performance while wearing the brace was likewise significant (F1,14=5.2, P=.04). Measures that were made at midrange or end range did not differ significantly; however, using only 1 arm to perform these tasks was associated with a sternal separation that was significantly wider, by 1mm, than when the tasks were performed bilaterally (F1,14=7.4, P=.02).

Sternal separation: arm elevation. The same pattern of significant results as for the previous tasks emerged. Having some support during arm elevation resulted in a mean sternal separation of 12.1mm, which was significantly less than the 13.4-mm separation without any support (F1,14=30, P<.001). Sports tape was less effective (by 2mm) than the supports worn on the body (F1,14=28.2, P<.001), and the compression garment was less effective than the fastening brace (F1,14=5.4, P=.04). The point in range in which the measure was taken exerted a consistent but small effect. The mean sternal separation at rest was 12.3mm, significantly lower than the 12.5mm at the end of the arm raise (F1,14=19.3, P=.001). Loading with a 1-kg weight did not produce a significant effect (F1,14=4.4, P=.054), but the separation when only 1 arm was used to lift it, at 12.9mm, was significantly larger than the 11.9mm measured for simultaneous bilateral movements (F1,14=6.1, P=.027). However, this 1-mm difference was relatively small in comparison to the effects caused by the different supportive devices, and, therefore, loading was not included in further analyses.

Sternal separation: overall. Confidence intervals for the effects of the different types of support pooled across both sternal separation analyses are given in table 4. Last, the order of intervention was substituted for the type of intervention so that in the ANOVA there was no significant order effect found (F3,14=.79, P=.51).

Table 3: Sternal Separation (in millimeters) During 2 Functional Tasks and During Arm Elevation Both Performed Unilaterally and Bilaterally

Table 4: The Mean Difference With 95% Confidence Limits for the Amount of Reduction of Sternal Separation (in millimeters) Associated With the Use of Successively More Supportive Devices

Table 4: The Mean Difference With 95% Confidence Limits for the Amount of Reduction of Sternal Separation (in millimeters) Associated With the Use of Successively More Supportive Devices

Patient Self-Report

All subjects reported a degree of pain at rest at the commencement of the study, and ratings ranged from 1 to 7 with a mean of 3.4 (see table 1).

Ratings after task performance. Participants gave ratings on 5 dimensions: ability to perform arm activities, discomfort, pain, feeling of support, and ease of breathing. For the purposes of carrying out a combined analysis, pain scores were subtracted from 10 to create a new dimension, pain attenuation, in which a high score represented a better outcome. Thereafter, ratings could be summed across dimensions. Mean ratings on the scales under the different types of supportive devices are given in table 5. The outcome of Helmert contrast analyses across the levels of support exactly matched that found for the sternal separation data. Thus, having some support led to higher ratings, by 1.1 scale points, than having no support (F1,14=22.8, P<.001). Sports tape was rated less positively by 1.7 scale points than the supports worn on the body (F1,14=8.0, P<.001), and the compression garment was rated 2 points lower than the adjustable fastening brace (F1,14=31.1, P<.001).

Last, open comments were solicited from the subjects. Thirteen of 15 subjects reported that they would have elected to wear a supportive device immediately after surgery, 8 stated that they thought that these devices would reduce the pain associated with all the activities of daily living, and 4 stated that the fastening brace reduced their low back pain. One subject reported that the straps on the fastening brace were bothersome, and another suggested that braces should be extended to incorporate the abdomen for additional support. In addition, 2 female subjects suggested that braces for women should have built in cups to accommodate breasts, and all 3

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female subjects stated that a support bra was more comfortable than any of the tested modes of intervention.

**DISCUSSION**

Results from the implementation of a set of supportive devices for patients with chronic sternal instability consistently favored the use of an adjustable fastening brace, which reduced the amount of sternal separation by one fifth. Measures tended to improve with the amount of support offered by the device. There were 2 exceptions to this pattern of perceived improvement with each additional level of support device, and these can be observed in table 3. Sports tape was rated as associated with more mean discomfort than having no support at all, and both sports tape and the compression garment were rated lower for ease of breathing than the no-support control condition.

Supportive devices may complement the dynamic stability role of the parasternal and anterior abdominal wall muscles and, in turn, provide stiffness to the segments of the spine, trunk, and chest wall during functional postural and movements.25,31 The wearing of a brace may counter the lateral forces that result from rises in intrathoracic pressures on coughing and the torsional forces that result from mobilization, upper-limb movements, and mobility transfers.25 They may also provide the necessary proprioceptive feedback to remind patients to brace their abdomen and chest before conducting activities. When being worn, braces provide additional support with tasks that the patient has little time to prepare for such as sneezing, coughing, or a sudden loss of footing. More importantly, we suggest that they serve to minimize pain and the interruptions to sleep secondary to excessive sternal motion that take place when the patient moves in bed at night (eg, from supine to side lying).

Interestingly, the women in this study commented that they preferred a bra to a supportive device. An explanation for this finding may be that although supportive devices offer circumferential support, little sternal compression results because the breasts create an observable space between the brace and the sternum. A support bra that has anterior clasps and wide shoulder straps may offer more comfort to females because it would minimize lateral tensile forces on the sternum and overlying tissues by supporting the breasts.

The existence of persistent poststernotomy pain at 1 month to 10 years after cardiac surgery is consistent with the findings of previous studies.2,3,20-24 The incidence reported in this study is higher because of the concurrent existence of sternal instability in this sample group.

**Study Limitations**

Limitations of this study were the small sample size and a patient group only including those with chronic, and not acute, sternal instability. Future research could be conducted with a larger number of patients that included a group with acute sternal instability. This would enable the assessment of the effects of supportive devices on symptoms for those awaiting surgical repair and permit the evaluation of supportive devices for those with chronic sternal instability when they negotiate their vocational duties or everyday tasks.

Cardiothoracic physiotherapy intervention after cardiac surgery entails active mobilization, coughing, and upper-limb exercises. The ability of patients to undertake these interventions is often limited by chest pain and coughing. The positive findings here regarding the effects of supportive devices on reported pain and ease of performance of everyday functional tasks in patients with sternal instability suggest that future studies should examine the use of supportive devices in the period immediately after cardiac surgery for their effect on both pain and sternal integrity.

**CONCLUSIONS**

Supportive devices may be useful in the management of patients with sternal instability because wearing one resulted in a reduction of both sternal separation and pain reported after movement. The largest effect was obtained from wearing an adjustable fastening brace.

**References**


Suppliers
a. Mefix sports tape; Mölnlycke Health Care, Ground Fl, Bldg 1, 14 Aquatic Dr, Frenchs Forest, NSW 2084, Australia.
b. FM elastoplasts; Capital Medical Supplies, Unit 3, 71 Heffernan St, Mitchel, ACT 2911, Australia.
c. Tubipad compression garment; Seton Healthcare Group, PO Box 395, Regents Park BC, 2143 Sydney, Australia.
d. Qualibreath fastening brace; Hjorth Health Pty Ltd, 22 Warath St, Seacliff, SA 5126, Australia.
e. Dornier Medizintechnik Gmbh, Postfach 1128, D-82101 Gernering, Germany.
f. Ausmedic Australia, PO Box 542, Hornsby, NSW 2077, Australia.
g. Version 14.0; SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.