Precautions related to midline sternotomy in cardiac surgery. Is there a connection between mechanical stress factors and sternal complications?

Barbara C Brocki, PT, PhD stud.
Dep. of Occupational Therapy and Physiotherapy
E.mail: bcb@rn.dk
Contents

1. Background
2. Sternal complications – definition, risk factors, pathogenesis
3. Sternal precautions – evidence and recommendations
4. Status
Background

- Sternal precautions are supposed to prevent sternal complications following heart surgery

- Precautions = restrictions

- Overly restrictive activity precautions can negatively affect patient recovery (lung function, activity level, quality of life).
Sternal complications

- Dehiscence
- Non – union
- Superficial infection
- Deep infection (mediastinitis)

- Incidence: 0.5 – 8.4 %, with high mortality rates in the presence of infections (14 – 47%) Olbrecht VA et al, 2006

- Most sternal wound complications are identified after hospital discharge (66%) Ridderstolpe L et al, 2001
Risk factors associated with sternal complications

- Patients characteristics
- Preoperative conditions
- Operative variables
- Postoperative conditions
Risk factors associated with sternal complications

<table>
<thead>
<tr>
<th>Primary risk factors</th>
<th>Secondary risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Obesity / high BMI</td>
<td>• Osteoporosis</td>
</tr>
<tr>
<td>• COPD</td>
<td>• Length of stay in the ICU</td>
</tr>
<tr>
<td>• Diabetes Mellitus</td>
<td>• Staple use for skin closure</td>
</tr>
<tr>
<td>• Early reoperation</td>
<td>• Impaired renal function</td>
</tr>
<tr>
<td>• Internal mammary grafting (bilat.)</td>
<td>• Paramedian sternotomy</td>
</tr>
<tr>
<td>• Surgery time</td>
<td>• Depressed left ventricular function</td>
</tr>
<tr>
<td>• Blood transfusions</td>
<td>• Emergency surgery</td>
</tr>
<tr>
<td>• Smoking</td>
<td>• Closure by noncardiovascular surgeon</td>
</tr>
<tr>
<td>• Female gender</td>
<td>• Overexertion/ loaded activities with one/two arms</td>
</tr>
</tbody>
</table>

Overexertion/ loaded activities with one/two arms
### Conditions and forces influencing healing of the sternotomy and skin site - from the mechanical point of view

<table>
<thead>
<tr>
<th>Helps keeping union of both sternum and skin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sternal wires location, number and tightness</td>
</tr>
<tr>
<td>Time</td>
</tr>
</tbody>
</table>

### Influences the healing process

<table>
<thead>
<tr>
<th>Pre-disposing conditions</th>
<th>Biomechanical mechanisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>COPD</td>
<td>Breathing</td>
</tr>
<tr>
<td>Macromastia</td>
<td>Activation of the pectoralis muscles</td>
</tr>
<tr>
<td>Obesity</td>
<td>Activation of the abdominal muscles</td>
</tr>
<tr>
<td>Suboptimal sternal closure</td>
<td>Loaded movements of the arms</td>
</tr>
<tr>
<td>Early surgical chest reoperation</td>
<td>Premature overexertion</td>
</tr>
<tr>
<td>Prolonged postoperative ventilation</td>
<td>Thorax muscles activation during cough</td>
</tr>
</tbody>
</table>
Timeframe for healing of the suprasternal skin and the sternum

- **10 days**
  - Suprasternal skin heals

- **2 weeks**
  - Bone healing – callus on X ray

- **4 weeks**
  - Bone surface is healed

- **6 - 8 weeks**
  - Complete sternal healing

---

**AALBORG HOSPITAL**
**AARHUS UNIVERSITY HOSPITAL**

**NORTH DENMARK REGION**
Biomechanical data

- Sternal separation occurs mostly as a result of sternal wires cutting through the bone.
- The lower part of the sternum is most susceptible to separation.

Robicsek et al, 2000
Biomechanical data

• Sternal separation
  * lateral direction
  * anteror-posterior direction
  * rostro-caudal direction

Mc Gregor et al, 1999
Common activity precautions

- Loaded activities with the arms – is there a limit? 2 kg? 5 kg? 10 kg?

- Lifting 2 kg requires a force of approximately 2.45 kg

Force required for activities of daily living

- Lifting a full coffee pot requires a force of \( \approx 2.95 \text{ kg} \).

Adams J, et al. 2006
Force required for activities of daily living

Opening a refrigerator door requires a force of ≈ 4 kg.

Adams J, et al. 2006
Force required for activities of daily living

- Opening a car door requires a force of $\approx 5.7$ kg.

Adams J., et al. 2006
What is the evidence for sternal precautions?

- Literature review:

- Methods
  ✓ Information about activity instructions from all five cardiothoracic centres in Denmark.
  ✓ Review of literature referring to mechanical stress of the sternal region regarding boned structures and skin.
## Oxford Centre for Evidence-Based Medicine

### Levels of Evidence

<table>
<thead>
<tr>
<th>Grades of Recommendations</th>
<th>Levels of evidence</th>
</tr>
</thead>
</table>
| **A**: Consistent level 1 studies | 1. Meta-analyses, SR* with homogeneity of RCTs**
|                           | Individual RCT with narrow confidence interval |
| **B**: Consistent level 2 or 3 studies or extrapolations from level 1 studies | 2. Non-Randomised controlled studies |
|                           | 3. Prospective cohort studies |
| **C**: Level 4 studies or extrapolations from level 2 or 3 studies | 4. Case-series, poor quality cohort and casecontrol studies |
| **D**: Level 5 evidence | 5. Case- studies, expert opinions |

Systematic Review ** Randomised Controlled Trials
Mechanical stress factors that may cause sternal complications after sternotomy

1. Frequent coughing
2. A constant pull on the thorax and ribcage for obese patients
3. Strain on sternum due to loaded movements of the arms
4. Skin stress leading to disruption of the surgical site
5. Skin stress due to hypertrophy mamma in women
6. Recruitment of the abdominal muscles when transferring from a lying to a sitting position
1. Frequent coughing

Intrathoracic pressure ~ 300 mmHg

Effect of supportive devices in chronic sternotomy problems (non-union)

1. Frequent coughing

Recommendation:

- Patients should be taught “self hugging” when coughing and sneezing during the initial 6-8 weeks following sternotony.
1. Frequent coughing

**Recommendation:**

- Patients should be taught “self hugging” when coughing and sneezing during the initial 6-8 weeks following sternotomy.

- Patients who cough frequently should wear a sternal vest that:
  * Supports the entire circumference of the thorax
  * Provides immediate support, because coughing and sneezing is spontaneous.
  * Is made of elastic material and designed to be worn 24 hours a day

*Grade D recommendation based on level 4 studies*
Supportive vest
Effect of supportive vest in the prevention of sternal dehiscence

- In patients with COPD – Celik et al, 2011
- Upgrading of evidence level?

**TABLE 2. Incidence and types of dehiscence in both studies**

<table>
<thead>
<tr>
<th>Study 1 (n = 842)</th>
<th>Study 2 (n = 221)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1a</td>
<td>Group 1b</td>
</tr>
<tr>
<td>COPD</td>
<td>Non-COPD</td>
</tr>
<tr>
<td>n = 328</td>
<td>n = 514</td>
</tr>
<tr>
<td>ISD</td>
<td>6 (1.8)</td>
</tr>
<tr>
<td>SSWI</td>
<td>4 (1.2)</td>
</tr>
<tr>
<td>DSWI</td>
<td>16 (4.9)</td>
</tr>
<tr>
<td>Total</td>
<td>26 (7.9)</td>
</tr>
</tbody>
</table>

*COPD, Chronic obstructive pulmonary disease; ISD, isolated sternal dehiscence; SSWI, superficial sternal wound infection; DSWI, deep sternal wound infection. Data are presented as n (%) for each group.*
2. A constant pull on the thorax and ribcage for obese patients
2. A constant pull on the thorax and ribcage for obese patients

Recommendation:

- Patients with BMI $\geq 35$ should wear a supportive vest for sternal protection during the initial 6-8 weeks following sternotomy.

Grade D recommendation based on expert opinion
3. Strain on sternum due to loaded movements of the arms

Lifting at arms length changes the lever arm, applying a higher force upon the sternum

3. Strain on sternum due to loaded movements of the arms

Recommendation:

- Loaded movements of the arms should be done, within pain level, keeping the upper arms close to the body during the initial 6-8 weeks following sternotomy.

*Grade D recommendation based on level 4 studies*
4. Skin stress leading to disruption of the surgical site during unloaded movements of the upper extremities

Supra-sternal skin movement (Irion et al, 2007)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Skin movement (Microvolts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifting 1 l milk – with one hand</td>
<td>230</td>
</tr>
<tr>
<td>Supine → long sitting (push up)</td>
<td>440</td>
</tr>
<tr>
<td>Supine → short sitting (leg roll)</td>
<td>350</td>
</tr>
<tr>
<td>Sit to stand (hand support to the side)</td>
<td>450</td>
</tr>
<tr>
<td>Sit to stand (without the use of hands)</td>
<td>390</td>
</tr>
<tr>
<td>Transfers produce more skin stress than lifting objects overhead (stand up vs lifting)</td>
<td>430 vs. 230</td>
</tr>
</tbody>
</table>
4. Skin stress leading to disruption of the surgical site during unloaded movements of the upper extremities

Recommendation

• Unloaded bilateral movements of the arms in the horizontal level, backwards, or over the shoulder level should only be performed within pain limits for 10 days after surgery or until the wound is healed, in order to avoid disruption of the incisional site.

*Grade D recommendation based on level 4 studies*
5. Skin stress due to hypertrofia mamma in women

Recommendation:

- Women with bra size ≥ D should always use a supportive brassiere shaped to provide entire chest circumference support during the initial 6-8 weeks following sternotomy. It should be fastened at the front and leave space for monitoring lines, enabling quick access to regular or emergency care.

Grade B recommendation based on level 3b studies
Supportive bra
6. Recruitment of the abdominal muscles when transferring from a lying to a sitting position

Muscles of the abdominal wall
The "elbow method"
6. Recruitment of the abdominal muscles when transferring from a lying to a sitting position

Recommendation:

- Patients should use the “elbow method” during transfers from lying to a sitting position during the initial 6-8 weeks following sternotomy.

Grade D recommendation based on level 4 studies
Recommendations (Brocki et al, 2010)

1. Avoid stretching both arms backwards at the same time
2. Movement which might stress the upper body should be done with the elbows close to the body
3. Only move arms within a pain free range
4. Use the “elbow method” when getting in and out of bed
5. Perform sternal preservation when coughing (crossing the arms in a “self hugging” posture)
6. Use a sternal support vest when frequent coughing or $BMI \geq 35$
7. Use a supporting brassiere that provides entire chest circumference support, if bra size $\geq D$
Is the use of sternal precautions evidence-based?

- Mostly indirect evidence
- Expert opinion
- Cadaver studies / material engineering / biomechanical models
- Obstacles for randomized controlled studies
- Low level of evidence
Experience with change of practice for sternal precautions – Aalborg Hospital

- Back to limits for armload – 5 kg for bilateral movements – some limit makes it easier for the patients to handle
- Difficult for many patients to handle level of activity according to pain
- Dehiscence occurs due to excessive stress on the sternum – not one time, but frequently/ overload
- Increase in cost – use of a supportive vest / Bra
- Some patients don't follow the recommendations at all
Change of practice for sternal precautions

• Observational study based on 579 participants (n=287 standard practice, n=292 changed practice)

Less restrictive protocol limiting the use of the upper limbs only according to pain does not result in an increase in postoperative sternal complications in the acute recovery phase

Mackney J et al, 16th WCPT Congress 2011

But what about sternal complications after hospital discharge?
Change of practice for sternal precautions (Cahalin LP et al, 2011)

SP algorithm based on number of primary & secondary risk factors, sternal instability scale score, pt. characteristics and clinical profiles - low, moderate, high risk patients

Low risk - 2 weeks after the operation
Aalborg Hospital
Forces exerted on the sternal region (Parker et al, 2008)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Force Range (kg-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cough</td>
<td>22 - 36 kg-m</td>
</tr>
<tr>
<td>5 lb weight</td>
<td>3 - 10 kg-m</td>
</tr>
<tr>
<td>30 lb suitcase</td>
<td>17 - 24 kg-m</td>
</tr>
<tr>
<td>2 x 20 lb weight</td>
<td>21 - 29 kg-m</td>
</tr>
<tr>
<td>24 lb child</td>
<td>15 - 21 kg-m</td>
</tr>
<tr>
<td>Lift 1 l milk to counter (unilateral)</td>
<td>7 - 17 kg-m</td>
</tr>
</tbody>
</table>