Dysaesthesia associated with sternotomy for heart surgery†

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Background. Chronic pain occurs in 40–50% patients following cardiac surgery. Dysaesthesia, either in the form of heightened or diminished skin sensation, are frequently associated with chronic neuropathic pain. Therefore, dysaesthesia in the early postoperative period may predict chronic pain. However, the character and causes of dysaesthesia in the early postoperative period are unknown. The aim of this study was to investigate the incidence, extent, and causes of dysaesthesia following cardiac surgery by sternotomy.

Methods. In a prospective cohort study, 50 patients undergoing sternotomy for cardiac surgery were admitted to the study: 38 underwent coronary artery bypass graft (CABG), nine valve surgery, and three combined surgery. Forty-eight hours postoperatively, acute pain was measured by four-point verbal scale. Manual pinprick and cotton wool brushing was used to detect the areas of dysaesthesia.

Results. Some form of dysaesthesia was found in 27 (54%) of the patients. Using multivariate regression analysis, the total area of dysaesthesia was positively associated with CABG surgery and the severity of postoperative pain (P<0.001).

Conclusion. Dysaesthesia is common in the early postoperative period following cardiac surgery using a sternotomy and is associated with CABG surgery. The association with severity of pain may indicate a neuropathic element that is unrelieved by conventional opioid analgesia.


Keywords: complications, hyperalgesia; complications, neuropathy; pain, chronic neuropathic; surgery

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Chronic pain, associated with the sternotomy wound, occurs in 40–50% of patients after cardiac surgery; 33–66% of these patients experience chronic pain lasting more than 3 months and in a 25–33%, it lasts more than 1 year.1–9 This pain often has an adverse effect on mood and it impairs activities of daily life for patients. Despite its frequency and importance, the causes of chronic pain are incompletely understood.

The aetiology of chronic pain following heart surgery is likely to be multi-factorial and to include nociceptive and inflammatory causes. Sternal mal-union would be the most overt of such causes, as would sternal wires and retained epicardial pacing-wires, especially when infected. Incomplete revascularization of the myocardium may result in ongoing ischaemia and consequently, angina may be another source of pain. Surgical damage to the intercostal nerves during heart surgery can arise from: sternal retraction stretching the nerves at the costo-vertebral junctions; harvesting the internal thoracic artery with diathermy; misplacement of the sternal wires and insertion of intercostal drains. It is likely that at least some of this nerve damage results in neuropathic pain.

Chronic neuropathic pain is associated with dysaesthesia, an unpleasant abnormal sensation.10 This can occur in the form of diminished or heightened sensation: hypoaesthesia (diminished sensation), hypoalgesia (diminished sensation from a painful stimulus), allodynia (pain from a stimulus that is not normally painful) and hyperalgesia (increased sensation from a painful stimulus) have all been reported in patients following heart surgery.5 11 12 As dysaesthesia and chronic pain are associated, it is reasonable to hypothesize that the nature and extent of dysaesthesia in the early postoperative period may be a marker for chronic pain. If the causes of dysaesthesia could be identified then it might be possible to change surgical techniques so as to prevent or minimize nerve injury and, so, the incidence and severity of

chronic pain. In addition, should it be possible to identify those patients who were likely to develop chronic pain, then it might be possible to target them therapeutically to prevent it occurring or ameliorate its severity.10

To our knowledge, there has been no quantification of dysaesthesia in the early postoperative period following cardiac surgery. Before exploring any possible association with chronic pain, it would be valuable to establish, as a measure of their importance, the character of dysaesthesia and how frequently it occurs. Therefore, the aims of this study were to investigate the incidence, extent, and causes of dysaesthesia following cardiac surgery by sternotomy.

Methods

Lothian Health Research Ethics Committee approved this study (LREC2003/1/1). Patients undergoing elective cardiac surgery with sternotomy and who had provided written informed consent, were recruited. Previous heart surgery, sternotomy, or dysaesthesia of the chest wall were exclusion criteria.

To investigate whether mood influenced the patient’s perception of dysaesthesia, it was assessed using the Hospital Anxiety and Depression (HAD) questionnaire administered on the afternoon before their surgery.13 Patient and operative characteristics were documented. Approximately, 48 h after their surgery, a four-point, categorical, verbal pain score was recorded and a sensory examination was performed. The time point was chosen to balance the identification of dysaesthesia arising acutely from surgery against diminished ability of patients to cooperate with the examination because tracheal intubation, sedation or any other reason for diminished conscious level.

Anaesthetic technique was dependent on individual consultant anaesthetists. Ninety minutes before surgery patients were pre-medicated with lorazepam 1–2 mg or temazepam 20–40 mg orally alone or with i.m. injections of atropine 0.3–0.6 mg and morphine 10–15 mg. I.V. propofol 1–2 mg kg\(^{-1}\), etomidate 0.1–0.2 mg kg\(^{-1}\), or thiopentone 1–3 mg kg\(^{-1}\) was used to induce anaesthesia, in addition to i.v. fentanyl 4–10 \(\mu g\) kg\(^{-1}\) or remifentanil 1–2 \(\mu g\) kg\(^{-1}\) \(\min^{-1}\). Neuromuscular block was with pancuronium 0.1 mg kg\(^{-1}\) or rocuronium 0.9 mg kg\(^{-1}\). Anaesthesia was maintained with i.v. propofol target controlled infusion 2–3 \(\mu g\) ml\(^{-1}\) and remifentanil 0.02–0.1 \(\mu g\) kg\(^{-1}\) \(\min^{-1}\), isoflurane 1–2%, or morphine 0.25 mg kg\(^{-1}\) h\(^{-1}\) and midazolam 0.004 mg kg\(^{-1}\) h\(^{-1}\).

I.V. propofol was used for hypnosis in the intensive care unit until tracheal extubation. Patient controlled analgesia with morphine or fentanyl i.v. was used from surgery up until the time of examination. Once oral intake was commenced paracetamol 1 g was given every 6 h and dihydrocodeine 30 mg as required to a maximum of 240 mg day\(^{-1}\). Dihydro-codeine was converted to a morphine equivalent dose using a factor of 0.1 and fentanyl using a factor of 10.

Verbal pain rating score

Three types of pain were evaluated at the examination: ‘whole body pain’ (pain anywhere on the body); ‘pain in the sternotomy site’; and ‘worst ever pain at any site since their surgery’. For each of these the patient was asked to quantify the severity of their pain by a four-point, categorical, verbal rating scale: no pain, 0; mild pain, 1; moderate pain, 2; severe pain, 3.

Sensory testing

Sensory testing was performed by the same investigator (PP) who was a medical student that had undergone teaching in neurological examination supplemented with specific training in elicitation of dysaesthesia. Examination technique was practised before the start of the study until the investigator’s technique was reproducible. Manually applied cotton wool and a disposable blunt pin (Neurotip, Morton Medical, London, UK) were used to detect the presence or absence, of dysaesthesia. These techniques of examining tactile and pain sensations were described in the late 19th century and were established neurological examination techniques by the early 20th century.14 15 All subjects were examined with a bare chest, lying semi-recumbent in bed, looking straight ahead so as to be unable to see their chest directly. The standardized sensory examination procedure was to obtain ‘reference’ sensations by brushing with cotton wool and pin-prick on the volar aspect of the forearm. Next, starting on an area with normal sensation on the chest wall or anterior shoulder, the cotton wool or Neurotip was repeatedly gently applied by hand to the skin in steps of approximately 1 cm moving towards the sternum wound. This process was repeated from all directions over an area bounded laterally by the mid-axillary line, superiorly by the clavicle and inferiorly by level of the umbilicus. As the location of the stimulus was moved medially towards the sternum, the patient was asked to verbally indicate if the sensation became ‘more sore’ (hyperalgesia) or ‘less sore’ (hypoalgesia) or remained the same to pin-prick. Similarly, cotton wool was applied to the skin and the patient asked to indicate when the sensation became abnormal either by diminished sensation (hypoalgesia) or becoming painful (allodynia).

If any dysaesthesia was noted, the boundary between it and normal sensation was marked on the chest with single-use felt-tip pens, using a different colour for each form of dysaesthesia. Pieces of tracing paper of a known weight per unit area were cut to the same size and shape as the areas of dysaesthesia, and their relative sizes and positions were noted on a diagram of the chest. The paper was then weighed and the areas of dysaesthesia were then calculated.

Statistical analysis

Unless otherwise indicated, data are presented as mean followed by standard deviation (SD) in brackets. Data were analysed using SPSS for Windows version 11, and Microsoft Excel. The primary outcome variable was the total area of
Dysaesthesia at 48 h following surgery. All data were entered into a univariate correlation (Pearson) matrix to identify variables that were significantly associated (P<0.05) with the total area of dysaesthesia and for the individual types of dysaesthesia. The areas of dysaesthesia were positively skewed on visual inspection of their distribution plots and so their natural logarithms were used as they had a near-normal distribution. Variables that were significant univariate correlates were then entered stepwise into a multivariate linear regression model to determine the predictors of the areas of dysaesthesia.

Study population
Effect size, along with significance criterion (α) and sample size, is integral to the calculation of statistical power. Population effect size is the degree to which the null hypothesis is believed to be false. The definitions of effect size index and its scale is provided in Appendix 1. Estimating that a maximum of six independent variables would be used in the multivariate linear regression model, with α set at 0.05, a sample of 97 patients would have 80% power to detect a moderate to large effect size.16

Results
Patient and operative characteristics
Fifty-eight patients were recruited during the period from February to May 2003; one patient died, two had cerebral vascular accidents, five were either unconscious or had too low a conscious level to be cooperative at 48 h. Fifty patients (32 male, 18 female), of a mean age of 63 [range 34–83] yr and mean body mass index of 27.5 (3.9) kg m⁻², were included in the study. Their median HAD scores (interquartile range) were: total 10 (7, 14), depression 3 (2, 5), and anxiety 7 (5, 10).

Thirty-eight of the patients underwent CABG surgery (two without cardiopulmonary bypass), nine had heart valve surgery, and three had combined surgery; all were performed through a median sternotomy. All patients underwent general anaesthesia and no regional technique was used. Sixteen patients had a left- and eight had right-internal mammary artery harvested (seven had both). The mean duration of surgery was 4 h 14 min (SD 58 min). Chest drains were positioned sub-sternally, rather than through an intercostal space; all were removed before examination. Four patients had diabetes mellitus.

Up until the time of examination, patients used a mean total dose of opioids that was equivalent to 80 (40) mg of morphine. During this time an average of 5.8 g (1.7) acetaminophen p.o. was administered. No local anaesthetic techniques were used for analgesia.

Dysaesthesia
Twenty-seven patients (54%) experienced some form of dysaesthesia; 23 (46%) had dysaesthesia on the left side and 16 (32%) had it on the right side. Most areas of dysaesthesia were located within a few centimetres of the midline and none extended laterally past the mid-axillary line. Areas varied in shape from oblong, to long thin strips of no common orientation. Specific types of dysaesthesia either occurred alone and also in combination (i.e. in the same area of skin) of hyperalgesia with allodynia or hypoesthesia with hypoalgesia. There was no combination of hyperalgesia with hypoesthesia or of allodynia with hypoalgesia. Eighteen patients had hypoalgesia, 14 had hyperalgesia, 11 had hypoesthesia, and three had allodynia. The distributions of dysaesthesia are presented in Table 1 and the areas of the four types of dysaesthesia on the left and right of the sternal midline are presented in Table 2.

Multivariate regression models
Total area of dysaesthesia
To limit the influence of type 1 error, the multiple types and sides of dysaesthesia were summarized as the maximum area of any form or combination of abnormal sensation. CABG surgery and total body pain score were found to be significant predictors of the total area of dysaesthesia whilst pericardial drains and their size and the use of and number of saphenous vein grafts were rejected from the model (Table 3). Undergoing heart valve surgery, which was a significant, negative univariate correlate of the area of dysaesthesia, was also rejected from the model as marginally non-significant. Given that a significant model was revealed, the sub-groups of dysaesthesia were then investigated.

Left- and right-sided dysaesthesia
The total area of left-sided dysaesthesia of any form, was associated with CABG surgery and total area of right-sided dysaesthesia; heart-valve surgery, the size of pleural drains and the use of LIMA or saphenous veins were rejected from the model. The total area of right-sided dysaesthesia was

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Incidence of dysaesthesia on the right-side alone, left-side alone, and both sides of the sternotomy wound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right only</td>
</tr>
<tr>
<td>Any dysaesthesia</td>
<td>4 (8%)</td>
</tr>
<tr>
<td>Hyperalgesia</td>
<td>4 (8%)</td>
</tr>
<tr>
<td>Allodynia</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>Hypoalgesia</td>
<td>2 (4%)</td>
</tr>
<tr>
<td>Hypoesthesia</td>
<td>1 (2%)</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Areas of dysaesthesia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area right (cm²)</td>
</tr>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Hyperalgesia</td>
<td>8</td>
</tr>
<tr>
<td>Allodynia</td>
<td>3</td>
</tr>
<tr>
<td>Hypoalgesia</td>
<td>8</td>
</tr>
<tr>
<td>Hypoesthesia</td>
<td>6</td>
</tr>
</tbody>
</table>
associated with the use of a right pleural drain and a Chaux sternal retractor and left-sided dysaesthesia. Undergoing CABG surgery, the use of a right internal mammary artery as a conduit and the number of chest drains used were all rejected from the model.

**Hypoalgesia**

The total area of hypoalgesia was only predicted by the degree of patient’s pre-operative anxiety: heart valve surgery and the number of vein grafts used were rejected from the model. The area of left-sided hypoalgesia was associated with the use of an LIMA conduit and the area of right-sided hypoaesthesia: undergoing heart valve or CABG surgery, the size of left pleural drain and the area of right-sided hypoaesthesia were rejected from the model. The area of right-sided hypoalgesia was associated with the area of left-sided hypoalgesia and the size of the right pleural drain that was used: the number of pacing wires, the area of left-sided hypoesthesia, the total

Table 3 Regression models for dysaesthesia. $r^2$, goodness of fit; $\beta$, standardized regression coefficients; CABG, coronary artery bypass grafting; LIMA, left internal mammary artery; RIMA, right internal mammary artery

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>$r^2$</th>
<th>$P$-value</th>
<th>Predictor variables</th>
<th>$\beta$</th>
<th>$P$-value</th>
<th>Rejected variables</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area of hypoalgesia</td>
<td>0.104</td>
<td>0.022</td>
<td>HAD Anxiety Score</td>
<td>0.323</td>
<td>0.022</td>
<td>Number of vein grafts</td>
<td>0.129</td>
</tr>
<tr>
<td>Left-sided dysaesthesia</td>
<td>0.300</td>
<td>&lt;0.001</td>
<td>Right-sided hypoesthesia (n=6)</td>
<td>0.351</td>
<td>0.006</td>
<td>CABG surgery</td>
<td>0.608</td>
</tr>
<tr>
<td>Right-sided dysaesthesia</td>
<td>0.460</td>
<td>&lt;0.001</td>
<td>Right-sided pleural drain (n=23)</td>
<td>0.407</td>
<td>0.001</td>
<td>Heart valve surgery</td>
<td>0.515</td>
</tr>
<tr>
<td>Total hypoalgesia</td>
<td>0.119</td>
<td>0.014</td>
<td>Medtronic retractor (n=9)</td>
<td>0.345</td>
<td>0.014</td>
<td>Dihydrocodeine</td>
<td>0.499</td>
</tr>
<tr>
<td>Left-sided hypoalgesia</td>
<td>0.360</td>
<td>&lt;0.001</td>
<td>Right-sided hypoesthesia (n=6)</td>
<td>0.516</td>
<td>&lt;0.001</td>
<td>Right-sided hypoesthesia</td>
<td>0.598</td>
</tr>
<tr>
<td>Right-sided hypoalgesia</td>
<td>0.385</td>
<td>&lt;0.001</td>
<td>Left-sided hypoesthesia (n=10)</td>
<td>0.476</td>
<td>&lt;0.001</td>
<td>Medtronic retractor</td>
<td>0.092</td>
</tr>
<tr>
<td>Total hypoesthesia</td>
<td>0.019</td>
<td>0.242</td>
<td>CABB surgery</td>
<td>0.345</td>
<td>0.014</td>
<td>Left-sided hypoesthesia</td>
<td>0.820</td>
</tr>
<tr>
<td>Right-sided hypoesthesia</td>
<td>0.362</td>
<td>&lt;0.001</td>
<td>Right-sided hyperalgesia (n=8)</td>
<td>0.426</td>
<td>0.001</td>
<td>Duration of operation</td>
<td>0.669</td>
</tr>
<tr>
<td>Total allodynia</td>
<td>0.170</td>
<td>0.003</td>
<td>Number of drains</td>
<td>0.413</td>
<td>0.003</td>
<td>Medtronic retractor (n=2)</td>
<td>0.880</td>
</tr>
<tr>
<td>Left-sided allodynia</td>
<td>0.761</td>
<td>&lt;0.001</td>
<td>Right-sided allodynia (n=3)</td>
<td>0.794</td>
<td>&lt;0.001</td>
<td>Duration of operation</td>
<td>0.510</td>
</tr>
<tr>
<td>Right-sided allodynia</td>
<td>0.851</td>
<td>&lt;0.001</td>
<td>Left-sided allodynia (n=2)</td>
<td>0.774</td>
<td>&lt;0.001</td>
<td>Medtronic retractor (n=2)</td>
<td>0.275</td>
</tr>
</tbody>
</table>

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dose of morphine equivalents administered postoperatively and the use of a right internal mammary artery as a conduit were all rejected from the model.

The multivariate regression models for the individual forms and sides of dysaesthesia are summarized in Table 3. Reciprocal relationships between left and right sides existed for hypoesthesia and allodynia but not for hyperalgesia or hypoalgesia.

**Discussion**

**Study limitations**

**Goodness of fit**
The multivariate, regression model only explained a third of the variance in the total area of dysaesthesia suggesting that important predictor variables were not identified. Unidentified predictors might include surgical techniques that cause nerve damage and were not quantified in the present study. For example, the extent and power of diathermy used to dissect the internal mammary arteries from the chest wall.

**Sensory testing**
As there may be inconsistency in force when applying any stimulus manually, greater information might have been obtained by measuring a ‘strength’ or ‘amplitude’ of the dysaesthesia using a calibrated method such as von Frey hairs. In addition, examining other sensory modalities, such as temperature, might also have produced further information. Furthermore, it is likely that at the time of sensory testing, the skin immediately around the sternal wound would have been oedematous. Any dysaesthesia resulting from oedema might resolve when it dissipated. This point should be taken into consideration in future study designs.

**Population size**
As this study was undertaken as part of an undergraduate degree, it was time limited. The population recruited was less than planned because throughput of patients was reduced as a result of relocation of the hospital and bed-blockages in the intensive care unit. For this reason, the study has an 80% power, with alpha set at 0.05 and seven independent variables, to detect associations that were of large effect sizes and may have failed to identify associations that had a small or moderate effect size.

**Outcome measure**
To limit the influence of type 1 statistical error that might arise from examining four different types both to the left and right of the sternum, we first chose to coalesce all the measures into one overall estimate of the maximum area of any form of dysaesthesia. However, this approach might be inappropriate if different mechanisms cause different types of dysaesthesia. For this reason, we went on to examine the individual areas of different dysaesthesia. Given the innervation of the thorax, it is reasonable to assume that the causes of injury to nerves may differ from left to right. However, as the areas of most types of dysaesthesia on the left and right of the sternum were significantly correlated with each other suggesting that the mechanism in some case might be bilateral or central in origin, we also elected to examine total areas of each dysaesthesia. Thus, the findings of the secondary analysis should be interpreted with caution as there are multiple outcomes and so prone to type 2 statistical error.

**Dysaesthesia and chronic pain**
Intercostal nerve damage may cause neuropathic pain through peripheral and central mechanisms. Neuropathic pain is characterized by an area of abnormal sensation and that the patient’s pain is co-existent with or within an area of sensory deficit. Often this is accompanied by a hyperpathic state including allodynia and hyperalgesia. Such dysaesthesia are found in association with chronic pain arising from other forms of surgery. Whilst, the association of dysaesthesia and chronic pain following heart surgery may not be causally related as appears to be the case following inguinal herniotomy, further investigation is merited given its frequency.

**Total area of dysaesthesia**
The findings of this study indicate, as has been reported previously, that dysaesthesia are more likely to occur following CABG surgery than other forms of surgery using sternotomy. The positive association with the severity of total-body pain might indicate that sternotomy wound pain is relieved by conventional postoperative analgesia based upon opioids and paracetamol but neuropathic pain is located remote from the wound and is unrelieved by these analgesics. Although this is a new finding following sternotomy, poorly relieved acute postoperative pain predicts chronic pain following other surgical procedures.

**Individual dysaesthesia**
As explained previously, some of the identified associations between areas of individual dysaesthesia may be spurious because of type 1 error. However, they merit consideration as surgical technique was a recurrent predictor.

**Left-sided dysaesthesia**
Both the areas of left-sided hypoalgesia and hypoesthesia were found to be associated with the harvesting of the LIMA. Left chest wall pain associated with ipsilateral hypoesthesia or allodynia is a common finding of other workers. Injury to the left intercostal nerve during surgery is the suspected aetiology, and is believed to arise from diathermy used to dissect the LIMA from the inside of the chest wall.

**Right-sided dysaesthesia**
Whilst chest drains may cause pleuritic pain, there is no recognized association between the use of pleural drains
and dysaesthesia. Inadvertent opening of the right pleural space occasionally occurs in any sternotomy and would be an indication for placement of a drain. However, a right pleural drain would routinely be used following dissection of an RIMA and indeed, the area of right-sided hypoalgesia was associated with the use of a RIMA.

Retractors

General trauma to the chest wall, sternocostal and costovertebral joints during rib retraction are known causes of bilateral and central pain.20 Specialized sternal retractors that are designed to facilitate harvesting of the internal mammary artery, such as the Chevalier retractor that was used in 80% of patients undergoing CABG surgery in this study, expose both sides of the sternum to more pressure than conventional sternal retractors and increase the incidence of sternal fracture four times.20 However, no association was found between the use of the Chevalier retractor and any area of dysaesthesia in the present study.

In contrast, the Chaux sternal retractor was associated with the areas of right-sided total dysaesthesia, hypoalgesia, and hyperalgesia. As this retractor was only used in three patients (6%), this relationship should be interpreted with caution unless it is established by a study of a larger population. A more reliable association was found between the Medtronic, which was used in 18% of patients, and the total area of hypoesthesia. Bilateral pressure on intercostal nerves as a consequence of excessive retraction of the costo-vertebral joints may explain this association.

Whilst the choice of sternal retractor might influence the development of dysaesthesia, the way in which they are used might also be important. Quantification of the degree and force of retraction as well as who used them would also be valuable in future studies.

In conclusion, dysaesthesia was found to be a frequent complication of heart surgery using a sternotomy and is most likely to occur following CABG surgery. Areas of hypoesthesia, hypoalgesia, hyperalgesia, and allodynia all occur with different incidences, distributions, and sizes. Further study is required to establish whether the occurrence of dysaesthesia in the early postoperative period following cardiac surgery predicts chronic pain.

Appendix 1

Effect size index for multiple or multiple partial correlation

\[ f^2 = \frac{R^2}{1 - R^2}. \]

Where:

- \( f^2 \) = Effect size ratio
- \( R^2 \) = squared multiple or squared multiple partial correlations.

Effect sizes:

- Small = 0.02
- Medium = 0.15
- Large = 0.35

References