Clinical question.

In adult cardiac arrest following open (including heart and lung transplantations) and closed heart surgery (P), does use of any specific interventions (I) as opposed to standard care (according to treatment algorithm) (C), improve outcome (O) (e.g., ROSC, survival)?

Is this question addressing an intervention/therapy, prognosis or diagnosis? Intervention

State if this is a proposed new topic or revision of existing worksheet: New Topic.

Conflict of interest specific to this question

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet? No

Search strategy (including electronic databases searched).

1. To search:

   a. EmBase (1980 to Week 30 2009)
      - Articles containing the MeSH terms
        - (“Resuscitation” OR “Heart arrest”) AND “Heart surgery”) -> 1875 results
        - or (“Resuscitation” OR “Heart arrest”) AND “Thoracotomy”) -> 379 results
      - Exploded, with all subheadings included.
      - Limited to human studies (as per exclusion criteria below)
   
   b. Medline (1950 to July week 3 2009)
      - Articles containing the MeSH terms
        - (“Cardiopulmonary Resuscitation” OR “Heart arrest”) AND “Thoracic surgery”) -> 106 results
        - or (“Cardiopulmonary Resuscitation” OR “Heart arrest”) AND “Thoracotomy”) -> 72 results
      - Exploded, with all subheadings included.
      - Limited to human studies (as per exclusion criteria below)
   
   c. the Cochrane database for:
      - Articles containing the MeSH terms
        - (“Cardiopulmonary Resuscitation” OR “Heart Arrest”) AND (“Thoracic surgery” OR “Thoracotomy”)
        -> 0 results
      - Exploded, with all subheadings included.

   2334 results were initially identified after 98 duplicates were discarded.

   2. To exclude irrelevant articles based on title, and, if necessary, abstract.
   
   2254 articles were excluded based on title or abstract.

   3. To read the full text of possibly relevant articles to determine adherence to inclusion criteria.
   
   22 articles were included after full review. 58 were excluded after full review, including manual review of reference lists.

   4. To manually review reference lists of included articles and other articles of possible relevance.
   
   8 articles were identified from reference lists and included.
State inclusion and exclusion criteria

Inclusion criteria:
1. Descriptions or studies;
2. Published in peer-reviewed journals;
3. Of human patients;
4. Who experience a cardiac arrest;
5. In the 28 day period following (=after closure) surgery that involves the heart;
6. And were treated with an intervention

Exclusion criteria:
1. Single patient case studies
2. Studies exclusively examining patients who have cardiac arrests during cardiac surgery
3. Studies with insufficient published information to establish compliance with inclusion criteria.
4. Laboratory studies

Number of articles/sources meeting criteria for further review:
30 articles were ultimately identified and included
## Summary of evidence

### Evidence Supporting Clinical Question - Resternotomy

<table>
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<tr>
<th>Good</th>
<th>Evidence</th>
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<tr>
<td></td>
<td>[Karhunen, 2006, 143]</td>
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<td>[Kriaras, 1996, 10], [Rousou, 1994, 11280]</td>
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**Level of evidence**

- **A** = Return of spontaneous circulation
- **B** = Survival of event
- **C** = Survival to hospital discharge
- **D** = Intact neurological survival
- **E** = Other endpoint

*Italics* = Animal studies

** = same patients in these two studies

**^** = similar patient group to Mackay 2002

### Evidence Neutral to Clinical question – Resternotomy

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<td>[Suominen, 2001, 127]</td>
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<td>[Kaiser, 1990, 903]</td>
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**Level of evidence**

* = unspecified subset of paediatric patients

^ = similar patient group to Mackay 2002

### Evidence Opposing Clinical Question - Resternotomy

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**Level of evidence**

* = Paediatric patients
### Evidence Supporting Clinical Question - Mechanical circulatory support

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* = paediatric patients

### Evidence Neutral to Clinical question – Mechanical circulatory support

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<tr>
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<td>[Chez, 2005, 513]$^{ABCDe}$ [Del Nido, 1992, II300]$^{BCDEe}$ [Duncan, 1998, 305]$^{ABCEe}$</td>
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* = paediatric patients

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### Evidence Supporting Clinical Question – Increased Compression Depth

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<td>Fair</td>
<td>[Maher, 2009, 662]$^E$ *</td>
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### Evidence Supporting Clinical Question – Cyclosporin in transplant recipients

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* = paediatric patients

**[Pratap, 2004, 605]DE**

### Evidence Neutral to Clinical question – Use of anti-arrhythmics

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* = paediatric patients

**[Kron, 1984, 317] CF**

### Evidence Neutral to Clinical question – Increased Adrenaline Doses

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**[Cipolotti, 1991, 430]ABCD**
A detailed and comprehensive literature review was performed, and identified studies were critically appraised according to pre-specified inclusion and exclusion criteria.

Of 30 included studies, two were level 2 studies and one was a level 3 study. Two (LOE=2 [Mackay, 2004, 66, Raman, 1989, 129]) were supportive of the use of resternotomy, and one (LOE=3[Rousou, 1994, II280]) was in opposition to the clinical question of mechanical circulatory support.

**Question: Resternotomy**

[Raman, 1989, 129] (LOE=2, fair quality, supportive) performed a retrospective cohort study with concurrent non-randomised controls. 39 consecutive patients with cardiac arrest following cardiac surgery were described. Of these 39, one group was treated with standard ALS care (15 patients), and the other standard ALS care followed after 5.6±2.2 minutes by resternotomy and ICCPR (24 patients), with this decision made by the attending surgeon/ intensivist.

![Resternotomy Group vs Standard ALS group](image)

<table>
<thead>
<tr>
<th></th>
<th>Resternotomy Group</th>
<th>Standard ALS group</th>
<th>p-value</th>
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</thead>
<tbody>
<tr>
<td>ROSC</td>
<td>21/24 (88%)</td>
<td>10/15 (67%)</td>
<td>0.12</td>
</tr>
<tr>
<td>STHD</td>
<td>18/24 (75%)</td>
<td>5/15 (33%)</td>
<td>0.012</td>
</tr>
<tr>
<td>Neur. intact survival</td>
<td>18/24 (75%)</td>
<td>3/15 (20%)</td>
<td>0.001</td>
</tr>
<tr>
<td>Long term survival</td>
<td>18/24 (75%)</td>
<td>5/15 (33%)</td>
<td>0.012</td>
</tr>
</tbody>
</table>

[Mackay, 2004, 66] (LOE=2, fair quality, supportive) described a partially prospective and partially retrospective non-randomised cohort study of n=174 consecutive cardiac arrests following cardiac surgery, with 134/174 ROSC, 70/174 STHD (40%), and 57/174 one-year survival.

Of these patients, 43 had a resternotomy with 11/43 STHD (26%). 11/32 with resternotomy in ICU had STHD, as compared with 0/11 with resternotomy on the ward.

Of the 134 patients who did not have a resternotomy, 59/134 (44%) had STHD (p=.02) No further outcomes were reported for this subgroup analysis. This is obviously a problematic comparison group, as there exists a substantial selection bias in that those who ultimately required resternotomy may have been a priori less likely to survive.

This paper included many of the same patients as Mackay 2002.

![Resternotomy Group vs No Resternotomy Group](image)

<table>
<thead>
<tr>
<th></th>
<th>Resternotomy Group</th>
<th>No Resternotomy Group</th>
<th>p-value</th>
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</thead>
<tbody>
<tr>
<td>STHD</td>
<td>11/43 (26%)</td>
<td>59/134 (44%)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

**Question: Mechanical Circulatory Support**

[Rousou, 1994, II280] (LOE=3, poor quality, supportive) reported a retrospective case series of n=16 adult patients with cardiac arrest following cardiac surgery, who received resternotomy and were placed on CPB in the ICU after 50±6.7 minutes of resuscitation. ROSC 15/16, STHD 9/16, long-term survival 8 or 9/16. (at 24 +/- 8.7 months; 1 lost to follow up).

As a comparison group, a case series of 13 patients who received resternotomy without CPB was described, of whom 2/13 had "survival" – which was not defined. No further outcome data was presented for these patients. (p=.03)

![Resternotomy + CPB vs Resternotomy but no CPB](image)

<table>
<thead>
<tr>
<th></th>
<th>Resternotomy + CPB</th>
<th>Resternotomy but no CPB</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>STHD</td>
<td>9/16 (56%)</td>
<td>2/13 (15%)</td>
<td>0.03</td>
</tr>
</tbody>
</table>

The remaining studies were all at levels of evidence 4 and 5, and described six different interventions:

1. Resternotomy
2. Mechanical circulatory support (+/- resternotomy as required)
3. Increased adrenaline dosing
4. Increased compression depth
5. Administration of Cyclosporin A
6. Anti-arrhythmic therapy

Assignation of studies to be supportive of, neutral, or opposing each clinical question was difficult in case series and cohort studies without comparison groups. For these studies, arbitrary markers were designated such that any study reporting survival to discharge exceeding 30% with n ≥ 10 was supportive; any study reporting survival to discharge below 10% with n ≥ 10 was in opposition, and all other studies were neutral. After this categorization, after discussion with the other worksheet authors 3 papers were reclassified: [Mackay, 2004, 66] to supportive, and [Kaiser, 1990, 903] and [Suominen, 2001, 127] to neutral.

1. Resternotomy

[Anthi, 1998, 15, Dimopoulou, 2001, 1408]. (LOE=4, good quality, supportive) both described a prospective cohort study (n=29) of patients who received emergent resternotomy after 5 minutes of standard ALS – ROSC 27/29, STHD 23/29. NIS 23/29, 1 year survival 20/29. Although there was no control group, patients were to a limited degree self-controlling, as all had failed ROSC after 5 minutes of standard ECC.

[Beyersdorf, 1992, 1141] (LOE=4, good quality, neutral) describe a case series (n=10) of whom 8 were post cardiac surgery, suffered cardiac arrest, and were given standard ALS as a bridge to theatre for resternotomy with CPB and warm blood cardioplegia. ROSC 8/10 STHD 6/8.

[El-Banayosy, 1998, 390] (LOE=4, good quality, supportive) published a retrospective cohort study (n=113) of adult patients with cardiac arrest following cardiac surgery, treated with standard ALS for 20-30 minutes, followed by IABP, then resternotomy if within 48 hours post surgery – ROSC 105/113 STHD 79/113.

[Fairman, 1981, 386] (LOE=4, good quality, supportive) published a retrospective cohort study (n=63) of patients requiring resternotomy in the ICU after cardiac surgery, with ROSC of 31/63, and STHD of 19/63. In a subgroup of 44 patients for whom the resternotomy was unpredicted (ie without preceding circulatory decline), ROSC was 25/44 and STHD was 19/44.

[Feng, 1995, 319] (LOE=4, good quality, neutral) published a retrospective case series (n=3) of patients with cardiac arrest following cardiac surgery who received resternotomy, OCCPR, and CPB. 3/3 ROSC, 3/3 STHD and 3/3 NIS.

[Kaiser, 1990, 903] (LOE=4, poor quality, neutral) reported on a retrospective cohort (n=110) who received resternotomy in the ICU, of which n=11 had the indication ‘resuscitation’. The outcome measure ‘survival’ (not further defined) was 2/11, with no mediastinal infections reported.

[Karhunen, 2006, 143] (LOE=4, fair quality, supportive) described a retrospective cohort (n=76) of adults who were treated with resternotomy for cardiac arrest following cardiac surgery. 41/76 STHD, 37/76 five-year survival. No protocol for treatment was described, and patients who did not receive resternotomy were not reported on.

[Kriaras, 1996, 10] (LOE=4, poor quality, supportive) retrospectively studied a cohort receiving resternotomy (n=12) to determine infection rates, and reported STHD 8/12.

[Mackay, 1998, 15] (LOE=4, good quality, supportive) reported on a prospective cohort (n=79) receiving resternotomies for cardiac arrest after cardiac surgery. Overall, 20/79 STHD, with considerable homogeneity dependent on patient location: 19/58 in ICU, but only 1/21 on the ward. This paper included many of the same patients as Mackay 2004.

[Ngaage, 2009, 64] (LOE=4, good quality, supportive) described a retrospective cohort study (n=108) of patients with cardiac arrest following CABG or AVR. Standard ALS protocol was performed, unless and until it failed to restore circulation, or ‘anatomic defect was suspected’, when resternotomy was performed. STHD = 54/108. Of the 108 studied, 45 received resternotomy, and 14 received CPB, but survival in these subgroups was not reported.

[Pottle, 2002, 269] (LOE=5, different patient group, good quality, neutral) describe a retrospective cohort (n=72) of adult and paediatric patients receiving resternotomy for cardiac arrest following cardiac surgery. They report ROSC 33/72 and STHD 12/72. None of the 13 patients who received resternotomy on a standard ward survived to discharge.

[Rousou, 1994, II280] (LOE=4, poor quality, supportive) provided evidence for the question of mechanical circulatory support, but also presents evidence in support of resternotomy. In this retrospective case series of n=16 adult patients...
who received resternotomy and were placed on CPB in the ICU after 50 +/- 6.7 minutes of resuscitation, 15/16 had. ROSC, 9/16 had STHD, and long-term survival was 8 or 9/16. (at 24 +/- 8.7 months; 1 lost to follow up).

[Suominen, 2001, 127] (LOE=5, different patient group, fair quality, neutral) published a retrospective non-randomised cohort study of n=82 consecutive paediatric patients who had cardiac arrest following cardiac surgery. 48/82 had resuscitation attempted. 27/48 ROSC 9/48 STHD 9/48 1-year survival 9/48 NIS 6/48. Of the 34/82 for whom no resuscitation was attempted, one was declared brain dead, and resuscitation was withheld in the remainder due to a determination of futility.

No further details on these subgroups were published. Large selection bias between groups, as those who proceeded to OCCPR were likely to have failed ECC attempts. Study was not designed to compare these groups.

[Wahba, 1997, 147] (LOE=4, good quality, neutral) describe a retrospective cohort of (n=42) adult patients who required CPR following cardiac surgery (of a total 2978 patients). Treatment was as per standard institutional protocol. 37/42 survived the event to 8 hours, 23/42 STHD, 23/42 NIS, 21/42 long term survival (mean 16 months). 29/42 received resternotomy, but the only statement regarding outcomes for this subgroup is "the mortality of this subgroup was not significantly higher", and therefore it is impossible to interpret this study as a controlled trial.

2. Mechanical circulatory support

[Chen, 2003, 197] (LOE=4, good quality, supportive) published a case series of n=57 patients treated with ECMO during CPR, of whom n=14 were post-cardiotomy. Of these 14 patients, 8 had STHD. Further outcome data in this subgroup is not published. The post-cardiotomy group had superior survival to the non-cardiotomy group, who had STHD after ECMO of 10/43 (not suitable as a control group). The rates of re-sternotomy were not published.

[Chez, 2005, 513] (LOE=5, different patient group, good quality, neutral) described a case series (n=15) of paediatric patients receiving ECLS, of whom n=4 were cannulated for cardiac arrest following cardiac surgery. 4/4 ROSC 4/4 STHD 4/4 NIS. The rates of re-sternotomy were not published.

[Dalton, 1993, 1020] (LOE=5, different patient group, good quality, neutral) described a retrospective cohort study (n=29) of paediatric patients, of whom n=7 received ECMO for cardiac arrest following cardiac surgery, with resternotomy if necessary (1 was cannulated percutaneously). 7/7 ROSC and 4/7 STHD

[Del Nido, 1992, II300] (LOE=5, different patient group, good quality, supportive) described a retrospective cohort study (n=33) of paediatric patients, of whom n=11 received ECMO for cardiac arrest following cardiac surgery, with resternotomy if necessary (1 was cannulated percutaneously). 11/11 ROSC 7/11 STHD 7/11 NIS 6/11 Long-term survival (at one month)

[Duncan, 1998, 305] (LOE=5, different patient group, good quality, neutral) described a retrospective cohort study (n=11) of paediatric patients, of whom n=9 received 'rapid deployment' ECMO. 5/9 STHD, 4/9 long-term survival. The rates of re-sternotomy were not published, although it was implied that re-sternotomy was performed in all patients.

[Newsome, 1992, 328] (LOE=4, poor quality, supportive) describe a retrospective cohort study (n=24) of adult patients, of whom n=10 received CPB for cardiac arrest following cardiac surgery. 10/10 ROSC and 4/10 STHD. The rates of re-sternotomy were not published.

[Overlie, 1995, 239] (LOE=4, good quality, positive) describes a prospective registry study of all patients receiving CPB (n=73), of whom n=11 were for cardiac arrest following cardiac surgery, without resternotomy. 5/11 ROSC 3/11 one-year survival.

[Parra, 2000, 3296] (LOE=5, different patient group, poor quality, supportive) reported on 32 Paediatric cardiac ICU patients with cardiac arrests, of which n=26 arrests were post-cardiac surgery (including 1 patient with 2 arrests). 16/26 ROSC, and 12/26 STHD. 4 patients had mechanical circulatory support instituted, of whom all 4 had STHD. Therefore, STHD was 8/22 without CPB; and 4/4 with CPB. No data on resternotomy or mode of access for CPB.
3. **Increased Adrenaline dosing**  
[Cipolotti, 1991, 430] (LOE=4, fair quality, neutral) described a case series of 2 patients who received higher doses of adrenaline (to over 15mg), with 2/2 STHD.

4. **Increased compression depth**  
[Maher, 2009, 662] (LOE=5, different patient group, fair quality, supportive) described a case series of 6 infants in whom ECC depth was increased to half the depth of the chest after five minutes of normal protocol (1/3 chest), with a resultant increase in systolic blood pressure to 83.4mmHg from 51.6mmHg. No clinical endpoints were reported.

5. **Administration of Cyclosporin A**  
[Pratap, 2004, 605] (LOE=5, different patient group, fair quality, supportive), described 15 infants post-heart transplant who were treated with cyclosporine A at the time of arrest, with STHD 8/15 and NIS 8/15. This was compared with 69 infants who did not have heart transplants and who were not treated with cyclosporine A, who had a STHD of 3/69 after cardiac arrest.

6. **Antiarrhythmic therapy**  
[Kron, 1984, 317] (LOE=4, fair quality, neutral) described a retrospective cohort study of n=18 patients with VF/VT following cardiac surgery, of whom n=17 were within 4 weeks. Before the arrhythmia, 6/17 had received no anti-arrhythmics, 6/17 received lignocaine, 2/17 received nitropresside and lignocaine, 1/17 received dobutamine, and 2/17 received dobutamine and lignocaine. The initial episode was fatal in 5/17. 9/17 had a recurrent arrhythmia in hospital despite antiarrhythmic therapy, of which 3/9 were immediately fatal. STHD was 9/17 of which 4/9 had EPS, of whom 3 are long-term survivors. 5/9 did not have EPS, of whom 4 are long-term survivors. It is difficult to draw any clinical conclusions from these findings.

**Articles describing standard care and outcomes only.**  
[Rhodes, 1999, II194] (LOE=5, different patient group, good quality) reported a retrospective cohort study of n=34 infants (under 1 year of age) with cardiac arrest following cardiac surgery, of whom 23/34 has ROSC, 20/34 survived the event, and 14/34 STHD. They all received standard care - ECMO was not available, and no information is published regarding resternotomy.

**Discussion Points**

The striking feature of the majority of these studies is the excellent outcome obtained in most patients. Cardiac arrest following cardiac surgery seemingly portends a superior prognosis to cardiac arrest in other hospitalized or community-dwelling patients, likely reflecting the increased chance of a reversible aetiology being responsible for the arrest.

Resternotomy is a widely accepted procedure, and is unlikely to be subjected to a randomized controlled trial. This acceptance is demonstrated by the publication by the European Association for Cardio-Thoracic Surgery of guidelines [Dunning, 2009, 3] that recommend, inter alia, early resternotomy in all types of cardiac arrest following cardiac surgery. This concords with standard practice, as recorded in a 2009 international survey of ICUs that in which respondents universally recommended resternotomy in cardiac arrest in the first 24 hours following cardiac surgery (after a median of 5 minutes) [Adam, 2009, 29]. Nevertheless, there remains insufficient evidence to make a scientifically based recommendation for routine resternotomy.

Of particular note is the observation that when performed in areas other than intensive care units (ICUs), resternotomy has a very poor prognosis, as demonstrated by the poor rates of survival documented in the included literature: 0/11 [Mackay, 2004, 66], 0/13 [Pottle, 2002, 269], and 1/21 [Mackay, 2002, 421]. It would be reasonable to recommend that the practice of resternotomy should generally be confined to ICU areas.

If resternotomy is to be considered as part of a standard resuscitation recommendation, non-chest compression based external cardiac massage techniques (for example, abdominal-only compressions) should be evaluated for suitability in order to reduce the pause in compressions due to the sternotomy procedure.

Adrenaline dosing remains a disputed question in cardiac arrest following cardiac surgery. The only study regarding adrenaline dosage that met inclusion criteria advocated higher levels of adrenaline. However, the preponderance of correspondence in the literature advocates reduced adrenaline dosing, and the EACTS guidelines specifically proscribe the use of adrenaline except where directed by senior staff. Despite this, there remains no evidence in human patients with cardiac arrest following cardiac surgery as to safe or effective dosing of adrenaline.
The use of mechanical circulatory support is demonstrated to be compatible with acceptable outcomes, and use as a bridge to eventual myocardial recovery (or transplantation) seems reasonable.

Notes:
The search strategy would be more focused and efficient had trauma been excluded from the outset, as there exist a large number of studies describing sternotomy for traumatic cardiac arrest which necessitated a time-consuming process of manual review and exclusion.

All p values were calculated using Fisher’s Exact Test.


Acknowledgements:
The Royal Melbourne Hospital Library for sourcing many papers.
Dr Emily Wilson for assisting with sourcing of papers.
**Citation List**


A survey indicating the high level of acceptance of early resternotomy in the first day following cardiac surgery.


Notes: LOE=4 (cohort study, good quality, supportive). n=29 (0.7% of a series of 3982 consecutive cardiac surgery patients). Protocol for all patients was conventional CPR for 3-5 minutes followed by resternotomy. 13/29 (45%) received ECC only; 16/29 (48%) proceeded to sternotomy. Control group lacking.

ROSC = 27/29.

STHD = 23/29

NIS = 23/29

1 year survival = 20/29


Notes: LOE=4 (case series; good quality, neutral). Good quality, although insufficient detail on inclusion criteria. 3 centres. n=14, of which 8 were post CABG. All arrested in the ICU, were treated with CPR (for 22-112 minutes), transferred to theatre for resternotomy, and placed on CPB with warm blood cardioplegia. 6 of 8 (75%) survived to hospital discharge and all 6 were alive at follow-up at 3-9 months. Other outcomes are not reported.


LOE=4 (Case series, good quality, supportive). Case series of n=57 patients treated with ECMO during CPR, of whom n=14 were post cardiotomy. Of these 14, 8 had STHD. Does not give subgroup data for ROSC or NIS in these 14. The non-cardiotomy group had STHD after ECMO of 10/43.


Notes: LOE=5 (different patient group, retrospective case series, no control group. Good quality. Neutral.). n=15 consecutive paediatric patients post-cardiac surgery receiving extracorporeal life support, of which n=4 were after cardiac arrest (defined as requiring CPR). All 4 were successfully weaned, and had neurologically intact survival to discharge.

Cardiac arrest usually carries a bleak prognosis when occurring in patients who have undergone open heart surgery. We report two cases where cardiac arrest was not responsive to routine therapies. Doses of epinephrine 5-10 times higher than recommended were able to provide a resolution, and the patients were discharged in a normal neurological state.

**Notes:** LOE=4 (retrospective case series, no control group. Fair quality. Neutral.) n=2 patients with cardiac arrest following cardiac surgery were treated with escalating doses of adrenaline, to a total of around 15mg in each patient. Both survived the event neurologically intact. ROSC 2/2 STHD 2/2 NIS 2/2.


**Notes:** LOE=5 (Different Patient Group. Retrospective cohort study, no comparison. Good quality. Neutral.). n=29 consecutive paediatric patients receiving ECMO, of which 7 were cannulated during CPR. 7/7 ROSC. 4/7 STHD. 4/7 NIS. 1/7 cannulated through neck. 6/7 through resternotomy. Of those given ECMO for poor output who had previously arrested, 8/13 had ROSC, and 8/13 survived to discharge.


**LOE=5 (Different Patient Group. Retrospective cohort study, no control. Good quality. Supportive)**

n=33 consecutive paediatric patients requiring ECMO, of which in n=11 the indication was cardiac arrest following cardiac surgery. 10/11 were cannulated via re-sternotomy. 7/11 STHD, 7/11 NIS, 6/11 long-term survival.


**Notes:** This study follows up the patient group initially described by Anthi et al.


**LOE=5 (Different patient group. Retrospective cohort study, no control. Good quality. Neutral.)**

n=11 consecutive paediatric patients with cardiac arrest, of whom n=9 were post-cardiac surgery. All received 'rapid deployment' ECMO. STHD 5/9, Long-term survival 4/9. Control group is specified as a historical cohort receiving non-rapid deployment ECMO, however the number of patients in the control group who were post-cardiac surgery is not published in this study. The reference given for those details (Duncan BW et al "Mechanical circulatory support for pediatric cardiac patients." *Circulation* 1996; 94 (suppl):I183) does not exist in the *Circulation* archives nor on PubMed.


A guideline for the management of cardiac arrest following cardiac surgery.

**Notes:** LOE=4 (Retrospective cohort study, no comparison. Good quality. Supportive). n=113 consecutive adults with cardiac arrest following cardiac surgery, treated as per standard ALS guidelines, with IABP after 20-30 minutes, followed by sternotomy if within 48/24 post CS. 105/113 ROSC, 79/113 STHD.


**Notes:** LOE=4 (Retrospective Cohort study, good quality, supportive). n=63 (one excluded as had only undergone EPS) patients with emergency rethoracotomy in the ICU; with a comparison between patients who had a sudden, unexpected indication for emergent thoracotomy and patients who had an inexorably declining circulatory status. Overall, ROSC + Survival of incident = 31/63 STHD = 19/63. In the sudden resternotomy group, ROSC was 25/44 and STHD was 19/44. In the 'expected' resternotomy group, ROSC was 7/19 and STHD was 0/19.


**LOE=4 (Retrospective case series. Good quality, neutral)** n=3 patients with cardiac arrest after cardiac surgery who were treated with resternotomy, internal cardiac compression, and CPB. 3/3 ROSC 3/3 STHD 3/3 NIS.


**Notes:** LOE=4 (Retrospective cohort study, poor quality, neutral). n=11 patients (of 1,259 consecutive cardiac surgery patients) received resternotomy for 'resuscitation' (not further defined). Survival was 18% (2/11), although it is not possible to determine the timing of follow-up.


**LOE=4 (Retrospective cohort. Fair quality. Supportive).** n=76 consecutive patients with cardiac arrest (requiring cardiac compression) following cardiac surgery were treated with resternotomy. 41/76 STHD. 5 year survival 37/76. 76 matched "controls" suffered no cardiac arrest - not truly a control group. Study not designed to assess intervention. No true control.


**LOE=4 (Retrospective cohort study. Poor quality. Supportive.)** n=12 consecutive patients with cardiac arrest after cardiac surgery (of 2140 total patients). STHD 8/12.

LOE=4. (Retrospective cohort study, fair, neutral). n=18 patients with VF/VT following cardiac surgery, of whom n=17 were within 4 weeks.
Before the arrhythmia, 6/17 had received no anti-arrhythmics, 6/17 received lignocaine, 2/17 received nitroprusside and lignocaine, 1/17 received dobutamine, and 2/17 received dobutamine and lignocaine.
The initial episode was fatal in 5/17.
9/17 had a recurrent arrhythmia in hospital despite antiarrhythmic therapy, of which 3/9 were immediately fatal.
STHD was 9/17 of which 4/9 had EPS, of whom 3 are long-term survivors. 5/9 did not have EPS, of whom 4 are long-term survivors.
It is difficult to know what conclusions to draw from this study.


Considerable heterogeneity:
Those within 24 hours of surgery have 15/40 (39%) STHD v 5/39 (13%).
Those reopened within 10 minutes of arrest have 14/29(48%) STHD v 6/50(12%).
Those reopened in ICU have 19/58 (33%) STHD v 1/21 (5%).
No control group.
No information on ROSC or NIS.
Quality is diminished as many patients - especially those in ICU - are likely to be missed due to not having cardiac arrest calls put out.


Notes: LOE=2 (Prospective/retrospective non-randomised cohort study, fair quality, supportive) n=174 consecutive cardiac arrests following cardiac surgery. 134/174 ROSC, 70/174 STHD (40%), 57/174 one-year survival.
134/174 did not have resternotomy, with 59/134 STHD (44%)
43/174 had resternotomy, with 11/43 STHD (26%) 11/32 with resternotomy in ICU had STHD. 0/11 with resternotomy on the ward had STHD.
Large selection bias for those who had resternotomy.


LOE=4 (Case series, fair quality). n=6 infants receiving CPR for cardiac arrest following cardiac surgery. After five minutes of normal compressions (to 1/3 of chest AP diameter), the depth was increased to half the chest depth. Systolic blood pressures increased from 51.6mmHg to 83.4mmHg.


LOE=4 (Retrospective cohort study, poor quality, supportive). n=24 adult patients treated with cardiopulmonary support, of whom n=10 were post-cardiac surgery. 10/10 ROSC, 4/10 STHD.
No information given on inclusion criteria, resuscitation protocol, use of re-sternotomy, or definitions of 'short-' and 'long-term survival'.


Notes: LOE=4 (Retrospective cohort study, Good quality. Supportive.) n=108 consecutive patients with arrest after CABG or AVR over 9 years. Standard ALS protocol was performed, unless and until it failed to restore circulation, or 'anatomic defect was suspected', when resternotomy was performed. STHD = 54/108. 45/108 received resternotomy, 14/108 received CPB.


Notes: LOE=4 (Prospective registry study, good quality, supportive). Multicentre registry of all patients receiving CPB, total n=73, of which n=11 were for cardiac arrest following cardiac surgery. 5/11 ROSC, Long-term survival 3/11 (at 1 year). Not explicitly stated, but it is implicit that CPB access was gained without resternotomy.


Notes: LOE=5 (Retrospective cohort study, poor quality, supportive). 32 Paediatric cardiac ICU patients with cardiac arrests, of which n=26 arrests were post-cardiac surgery (including 1 patient with 2 arrests). 16/26 ROSC (which includes successful CPB according to this study) 12/26 STHD in 46%. 4 patients had mechanical circulatory support instituted, of whom all 4 had STHD. Therefore, STHD was 8/22 without CPB; and 4/4 with CPB. No data on resternotomy or mode of access for CPB.


Notes: LOE=5 (Retrospective cohort study, good, neutral) n=72 consecutive adult and paediatric patients who received resternotomy and internal cardiac compression for cardiac arrest following cardiac surgery. 33/72 ROSC and 12/72 STHD. 0/13 STHD in those who arrested on the wards. The authors suggest a revised ALS algorithm. No subgroup analysis for adult/paediatric, therefore required to be LOE=5.


Notes: LOE=5 (Retrospective cohort study, fair quality, supportive). n=15 infants post-heart transplant with cardiac arrest who were treated with Cyclosporine A the time of arrest. 8/15 STHD, 8/15 NIS. Comparison group was patients with cardiac arrest who had not had a heart transplant and may not have had cardiac surgery - invalid comparison. Abstract only available.


Notes: LOE=2 (Retrospective cohort study with concurrent non-randomised controls, fair, positive) n=39 consecutive patients with cardiac arrest following cardiac surgery, of whom n=24 received
resternotomy and internal CPR within the ICU, following standard ECC (Resternotomy performed at 5.6+/- 2.2 minutes), and n=15 received standard CPR only.
ROSC - 21/24 in resternotomy group v 5/15 in standard CPR group
STHD - 18/24 in Resternotomy group. 5/15 in standard CPR group.
NIS: 18/24 v 3/15
Long-term survival (1-36 months) - 18/24 v 5/15


Notes: LOE=5 (Retrospective cohort study, good quality, positive). n=34 infants (under 1 year of age) with cardiac arrest following cardiac surgery. 23/34 has ROSC, 20/34 survived the event, and 14/34 STHD. Received standard care - ECMO was not available, and no data on resternotomy.


Rousou JA, Engelman RM, Flack IJE, Deaton DW, Owen SG. "Emergency cardiopulmonary bypass in the cardiac surgical unit can be a lifesaving measure in postoperative cardiac arrest". Circulation. 1994;90(II):II280.

LOE=3 (Retrospective case series. Poor quality. Positive). n=16 adult patients post-cardiac surgery with cardiac arrest who were treated with resternotomy and placed on CPB in the ICU, 50+/-6.7 minutes after arrest. ROSC 15/16, STHD 9/16, long-term survival 8 or 9/16. (at 24 +/- 8.7 months; 1 lost to follow up). Figures for ROSC were extrapolated from published data by this author (Ross).
Comparison: identified 13 patients who received resternotomy without CPB over 10 years, with 2/13 "survival" - not defined. No further data on these patients.


Notes: LOE=5 (Retrospective non-randomised cohort study, fair, neutral). n=82 consecutive paediatric patients had cardiac arrest following cardiac surgery. 48/82 had resuscitation attempted. 27/48 ROSC 9/48 STHD 9/48 1-survival 9/48 NIS 6/48.
Of the 34/82 for whom no resuscitation was attempted, one was declared brain dead, and resuscitation was withheld in the remainder due to a determination of futility.
35/48 received OCCPR following sternotomy - 5/35 1-year survival (14%)
13/48 received ECC only - 4/13 (30%) 1-year survival. No further details on these subgroups were published.

The specified "control group" was entirely patients who did not suffer cardiac arrest - invalid as controls.

LOE=4 (Retrospective cohort study, good, neutral) of n=42 adult patients who required CPR following cardiac surgery (of total 2978 patients). Treatment was as per standard protocol. 37/42 survived event to 8 hours. 23/42 STHD. 23/42 NIS. 21/42 long term survival (mean 16 months) all NYHA 1 or 2 29/42 received resternotomy, but the only statement regarding outcomes for this subgroup is "the mortality of this subgroup was not significantly higher".