External cardiac compression during cardiopulmonary resuscitation of patients with left ventricular assist devices

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Abstract

A best evidence topic was written according to a structured protocol to determine whether there is evidence that cardiopulmonary resuscitation (CPR) by compressing the chest is safe and effective in patients with left ventricular assist devices (LVADs). Manufacturers warn of a possible risk of device dislodgement if the chest is compressed. AMED, EMBASE, MEDLINE, BNI and CINAHL were searched from inception to March 2014. Animal studies, case reports, case series, case–control studies, randomized controlled studies and systematic reviews were eligible for inclusion. Opinion articles with no reference to data were excluded. Of 45 unique results, 3 articles merited inclusion. A total of 10 patients with LVADs received chest compression during resuscitation. There was no report of device dislodgement as judged by postarrest flow rate, autopsy and resumption of effective circulation and/or neurological function. The longest duration of chest compression was 150 min. However, there are no comparisons of the efficacy of chest compressions relative to alternative means of external CPR, such as abdominal-only compressions. The absence of high-quality data precludes definitive recommendation of any particular form of CPR, in patients with LVADs. However, data identified suggest that chest compression is not as unsafe as previously thought. The efficacy of chest compressions in this patient population has not yet been investigated. Further research is required to address both the safety and efficacy of chest compressions in this population. Urgent presentation and publication of further evidence will inform future guidance.

Keywords: Left ventricular assist device • External cardiac compression • Chest compression • Cardiopulmonary resuscitation

INTRODUCTION

It is unknown whether cardiopulmonary resuscitation (CPR) by compressing the chest is safe and effective in patients with left ventricular assist devices (LVADs). Manufacturers warn of a possible risk of device dislodgement if the chest is compressed. This may influence clinical practice. For example, Rottenberg et al. [1] presented a case of an on-table cardiac arrest in a patient undergoing re sternotomy for LVAD change. The surgeon opted for abdominal-only cardiopulmonary resuscitation (AO-CPR), fearing damage to inflow cannula with external cardiac compressions (ECCs). This theoretical risk is thought to be greater with larger preperitoneal devices, such as HeartMate II [2]. The 2009 European Association for Cardio-Thoracic Surgery guidelines on resuscitation following cardiac surgery [3] do not address this particular scenario, possibly because of a paucity of evidence at the time of guideline generation. Controversy remains regarding the risk of ECC in patients with LVADs. Therefore, a best evidence topic was constructed according to a structured protocol fully described in the ICVTS [4] to review and appraise the current evidence describing the role of ECC in resuscitating patients with LVADs.

THREE-PART QUESTION

In [cardiopulmonary resuscitation of patients with left ventricular assist devices], can [external cardiac compression] be performed [safely]?

CLINICAL SCENARIO

A patient, 11 months post-LVAD implantation, suffers a cardiac arrest confirmed by the internal machine alarm, machine auscultation and capillary refill as well as confirmed ventricular fibrillation. Commencing ECC risks dislodging the LVAD and there are no current guidelines available to guide the management of this emergency scenario.

SEARCH STRATEGY

The AMED, EMBASE, MEDLINE, BNI and CINAHL databases were searched from inception to March 2014 using the terms ‘cardiopulmonary resuscitation’ OR ‘CPR’ OR ‘external cardiac...
Although not explicit in the published abstract, chest compressions were performed for 30 min while extracorporeal life support (ECLS) was established. There were no immediate neurological deficits and the patient underwent emergency reperfusion for LVAD exchange. No mention was made of the state of the old LVAD upon retrieval. However, the patient made satisfactory progress and was discharged from the intensive care unit after 10 days. Satisfactory neurological function also suggests that LVAD integrity was maintained. The patient suffered another cardiopulmonary arrest on Day 11. Although not explicit in the published abstract, chest compressions were not attempted because the in situ LVAD was functioning. The patient expired before the alternative plan, central ECLS cannulation, could be instituted.

The most recent article was a retrospective case series analysis by Shinar et al. [10] in 2014. As the only article that was not a case report, this publication represents the highest level of evidence available for this topic. The series documents the outcomes of chest compressions in 8 patients (7 males, 1 female), all with HeartMate II LVADs over a 4-year period. The mean age was 66.4 (range, 50–80) and the mean duration from LVAD implantation to arrest was 460.9 days (range, 50–1324). The longest duration of chest compression was 150 min, 1 was 15–20 min, another 10–15 min and 1 was less than a minute. In 2 patients the duration of compression was unclear and the remaining patient received 2 intercalated episodes of compression, 5 and 3 min in duration, respectively. Four patients (50%) had a resumption of both neurological and effective circulatory functions. Seven patients (87.5%) had stable postarrest pump flow (3.7–6.6 l/min). Postarrest pump flow was not documented in 1 patient but autopsy revealed no LVAD disruption in this patient. Autopsies on 2 other patients also did not reveal LVAD disruption. The patient who had received 150 min of chest compression and the other patient compressed on 2 separate occasions showed no sign of LVAD impairment. In this series, there was no evidence of LVAD dislodgement or cannula disruption in any of the 8 patients who received chest compressions.

These 10 cases suggest that LVADs are not an absolute contraindication to ECC and/or chest compression. However, this systematic review is limited by nonuniform reporting of outcomes in the published cases. The depth of analysis was also limited by the absence of full-length articles expanding the case presentations and including authors’ discussions. Shinar et al. [10] acknowledged several potential limitations to their relatively large series. In patients not autopsied, flow rate was used as a surrogate for LVAD integrity. However, small cannula disruption does not always lead to flow disruption. The authors acknowledged that flow rate alone is not 100% sensitive, although the clinical relevance of small, flow-preserving disruptions is unclear. Also, the diagnosis of arrest can be difficult in patients with non-pulsatile LVADs because they do not have peripheral pulses [11]. The diagnostic criteria for each case are not specified.

Given the nature of the subject, it may be difficult to perform randomized controlled trials in humans to provide the high-quality evidence required to support firm conclusions. Studies of animal models may be useful to provide objective assessments of LVAD function post ECC under laboratory conditions. Randomized and controlled comparison of ECC with alternatives, such as AO-CPR and minimally invasive direct cardiac massage, which some suggest are more effective than ECC [12], might also be possible. The evidence supporting the use of AO-CPR in general has not yet been established [13] and further research is required.

Despite the absence of consensus guidelines, we identified 2 published local guidelines (not eligible for inclusion in this review but found through the search) that advocated chest compression in patients with no determinable flow in a non-functioning LVAD [5, 11]. The efficacy of chest compressions is thought to be lower in this group and the risk of retrograde flow through the outflow higher in this subgroup [10]. However, the magnitudes of these risks need to be ascertained so they can be balanced with the risk of death.

**CLINICAL BOTTOM LINE**

The absence of high-quality data precludes definitive recommendation for or against any particular form of CPR in patients with LVADs. However, data presented suggest that chest compression is not as unsafe as previously thought. The efficacy of chest compressions in this patient population has not yet been investigated. Further
Table 1: Best evidence papers

<table>
<thead>
<tr>
<th>Author, date, journal and country</th>
<th>Patient group</th>
<th>Outcomes</th>
<th>Key results</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chandekar and Vitale (2010), J Am Geriatr Soc, USA [8]</td>
<td>70-year-old male with ischaemic cardiomyopathy</td>
<td>Return of effective circulation</td>
<td>No objective measures presented. Patient survived and gradually improved and was transferred to a nursing home so is assumed to have had a resumption of effective circulation</td>
<td>This case was available only as a conference proceeding abstract and, therefore, critical details could not be extracted. These include the type and duration of CPR. It is reasonable to assume that chest compressions were administered because a deviation from this is likely to have been noteworthy enough to have justified inclusion in the abstract. The duration between driveline disconnection and initiation of CPR is also unclear. Therefore, it is additionally unclear whether anoxic brain injury was the result of LVAD dislodgement following CPR or had occurred before CPR was initiated. There is also no discussion of subsequent LVAD replacement. Given these caveats, it can only be assumed that, in this case, CPR did not result in LVAD dislodgement</td>
</tr>
<tr>
<td>Case report (level 4)</td>
<td>LVAD: centrifugal pump (with magnetic levitation)</td>
<td>Complete recovery and LVAD exchange</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cause of arrest: accidental fall resulting in disconnection of connection between controller battery and main pump</td>
<td>Return of neurological function</td>
<td>Patient suffered anoxic brain injury. It is unclear whether this was because of LVAD dislodgement or the delay in CPR initiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment: CPR performed by paramedics</td>
<td>Postarrest LVAD flow rate</td>
<td>Not reported</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chandekar and Vitale (2010), J Am Geriatr Soc, USA [8]</td>
<td>LVAD: HeartMate II</td>
<td>Return of effective circulation</td>
<td>There were no immediate neurological deficits</td>
<td></td>
</tr>
<tr>
<td>Retherford et al. (2012), Crit Care Med, USA [9]</td>
<td>46-year-old woman who had undergone LVAD implantation in 2009</td>
<td>Complete recovery and LVAD exchange</td>
<td></td>
<td>No mention was made of the state of the old LVAD upon retrieval. However, the patient made satisfactory progress and was discharged from the intensive care unit after 10 days. Satisfactory neurological function also suggests that LVAD integrity was maintained. The patient suffered another cardiopulmonary arrest on day 11. Although not explicit in the published abstract, chest compressions were not attempted because the in situ LVAD was functioning. The patient expired before the alternative plan, central ECLS cannulation, could be instituted</td>
</tr>
<tr>
<td>Case report (level 4)</td>
<td>LVAD: HeartMate II</td>
<td>Complete recovery and LVAD exchange</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cause of arrest: driveline disruption and power failure</td>
<td>Postarrest LVAD flow rate</td>
<td>Not reported</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPR: chest compressions were performed for 30 min while ECLS was established</td>
<td>Postarrest LVAD integrity</td>
<td>Not specifically mentioned but assumed from clinical improvement and no mention of LVAD exchange</td>
<td></td>
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</tr>
<tr>
<td>Shinar et al. (2014), Resuscitation, USA [10]</td>
<td>8 patients (7 males, 1 female), mean age was 66.4 (range 50–80) and mean duration from LVAD implantation to arrest was 460.9 days (range 50–1324)</td>
<td>Return of effective circulation</td>
<td>6 (75%)</td>
<td>This is the largest series yet showing no evidence of LVAD dislodgement as a surrogate for LVAD integrity. However, small cannula disruption does not always lead to flow disruption. Therefore, flow rate alone is not 100% sensitive</td>
</tr>
<tr>
<td>Case series (level 3)</td>
<td>LVAD: all had HeartMate II LVADs</td>
<td>Return of neurological function</td>
<td>4 (50%)</td>
<td></td>
</tr>
<tr>
<td>Causes of arrest: accidental disconnect (4), driveline malfunction (1), LV thrombus (1), VF (1), unclear (1)</td>
<td>Postarrest LVAD flow rate</td>
<td>3.7–6.6 l/min in 7 of 8 patients. The remaining patient had confirmed intact LVAD cannulas at autopsy</td>
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<td></td>
</tr>
<tr>
<td>CPR: 150 min, 15–20 min, 10–15 min, &lt;1 min, unclear duration in 2 patients and 1 patient received 2 intercalated episodes of compression, 5 and 3 min in duration, respectively</td>
<td>Postarrest LVAD integrity</td>
<td>Three autopsies were performed, all showing intact cannulas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cause of arrest: driveline malfunction (1), LV thrombus (1), VF (1), unclear (1)</td>
<td></td>
<td></td>
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<td>In patients not autopsied, flow rate was used as a surrogate for LVAD integrity. However, small cannula disruption does not always lead to flow disruption. Therefore, flow rate alone is not 100% sensitive</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>The diagnosis of arrest can be difficult in patients with non-pulsatile LVADs because they do not have peripheral pulses. The diagnostic criteria for each case are not specified</td>
</tr>
</tbody>
</table>
research is required to address both the safety and efficacy of chest compressions in this population. Urgent presentation and publication of further evidence will inform future guidance.

Conflict of interest: none declared.

REFERENCES


Mabvuure and Rodrigues [1] published results from their ‘best evidence’ search, to determine whether cardiopulmonary resuscitation (CPR) by sternal compression is safe and effective in patients with left ventricular assist devices (LVADs). They concluded that the absence of high-quality data precludes definitive recommendation of any particular form of CPR (thoracic or abdominal). They suggested that chest compression is not as unsafe as previously thought, but acknowledged that the safety and efficacy of sternal compressions in this patient population has not yet been investigated and recommended further research to inform future guidance. However, existing evidence suggests that the thoracic configuration of the patient determines whether sternal compression is either safe and effective or contraindicated [2–5]. Scherner and colleagues [2] published a case report regarding their experience with destruction of a percutaneous aortic valve implant during postoperative CPR necessitated by a refractory ventricular arrhythmia unresponsive to defibrillation and drug therapy. After a total of 75 minutes of CPR, they determined that life-support action was no longer effective and the patient subsequently died. Autopsy findings revealed compression and deformation of the aortic valve prosthesis as the only abnormality caused by CPR, which most likely led to failed resuscitation. To prevent this fatal complication in future cases, they developed an alternative method of chest compression in which one rescuer compresses the left hemithorax over the apex of the heart to avoid compressing the valve while a second rescuer uses two hands to provide a stabilizing force over the right hemithorax. They reported successful use of this method in another patient who required resuscitation after transcatheter aortic valve implantation. Rottenberg and collaborators [3] suggested that damage to the percutaneous valve could be explained by a study of transesophageal echocardiography performed during standard CPR in 34 adults showing significant narrowing of the left ventricular outflow tract (LVOT) (59% of patients) or the aortic root including the aortic valve (41% of patients), with the degree of compression at the area of maximal compression ranging from 19% to 83% (mean ± SD = 49 ± 19%). Computed tomography (CT) assessments of adults estimate that when chest compressions are performed over the internipple line (the adult guidelines recommended hand position), the ascending aorta (AA) (18.0%), the root of aorta (48.7%), the left ventricular inflow tract (LVIT) (20.6%) or LVOT (12.7%) were the structures underlying the “compression point of the sternum” (or area of maximal compression underneath the sternum) [4]. CT assessments of the paediatric chest (ranging from 1–10 years) estimate that when chest compressions are performed over the lower third of the sternum (the paediatric guidelines recommended hand position), the AA, the LVIT, LVOT, or liver underlie the compression point in 0%, 66.9%, 4.4% or 28.7% of all cases, respectively [5]. These data suggest that sternal compression is likely both safe and effective in only 20.6% and 66.9% of adult and paediatric patients with LVADs, respectively.

Conflict of interest: none declared.

References


