CASE REPORT

Mechanical CPR in a child: can one size fit all?

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Accepted 12 April 2017

SUMMARY

This case report describes the successful resuscitation of an 11-year-old boy who suffered out-of-hospital cardiac arrest (OHCA) using mechanical cardiopulmonary resuscitation (CPR) by adapting the Lund University Cardiopulmonary Assist System (LUCAS)² Device by rolling a blanket under the patient's back to increase his chest height, thus allowing the LUCAS device to administer compliant CPR.

BACKGROUND

Paediatric out-of-hospital cardiac arrest (OHCA) is extremely rare with survival remaining <10%¹ and for those who do survive there is a typically a very poor neurological outcome. Favourable outcomes in these situations rely on early, effective cardiopulmonary resuscitation (CPR) according to Advanced Life Support (ALS) principles. This in itself can be difficult in the paediatric population with fewer occurrences and hence less experience.

In the adult population, the use of mechanical CPR devices has revolutionised the way we treat patients in cardiac arrest particularly in the pre-hospital and transfer setting. Following successful charity funding in the Isle of Man (IOM), £117 000 was co-opted to introduce a Lund University Cardiopulmonary Assist System (LUCAS) Scheme across the Island's Ambulance Service, Nobles Hospital Emergency Department and the Minor Injury Unit. Therefore, for the past 4 years, all frontline ambulances have been equipped with the LUCAS² CPR device. Following its introduction, the IOM Ambulance service has demonstrated a sustained OHCA return of spontaneous circulation (ROSC) rate of 30%, whereas prior to this their ROSC rate was estimated at 16%.²

While the LUCAS manufacturer guidelines state it is 'contraindicated in children or small people where the distance between the pressure pad and the patient's sternum exceeds 15 mm',³ we present a case where adapting the LUCAS device using a blanket has led to a positive outcome for a child who sustained an OHCA.

We believe that in this case, we demonstrated that in extreme circumstances, mechanical devices such as LUCAS can be used on a child. This case report also highlights that mechanical CPR might be feasible in selected cases however further studies would be required to gain an evidence base to prove that it can be safe and effective in a paediatric population.

CASE PRESENTATION

An 11-year-old boy was walking alongside his mother to see his general practitioner (GP) regarding repeated asthma attacks. He suddenly collapsed and did not appear to be breathing. A 999 call from the patient's mother indicated that her son was in cardiac arrest and therefore multiple crews including police and first responders were dispatched to the scene. A bystander was able to start CPR while awaiting emergency medical personnel assistance. Police arrived on scene and alerted the local GP practice who sent their duty doctor out to help. Police officers continued to administer good-quality CPR while the paramedics and GP initiated ALS. Once the defibrillator was attached, it showed an asystolic rhythm. Intravenous access was gained, adrenaline was administered and they continued following the ALS non-shockable rhythm algorithm. The paramedics prepared to intubate the patient on scene and set up inline nebulised Salbutamol due to the presumed cause of life-threatening asthma exacerbation leading to hypoxic cardiac arrest. The journey time to the hospital was estimated to be approximately 20 min and there was concern about how they could carry out guideline compliant CPR and continue to administer ALS in the back of the ambulance. At the time of transfer the patient had been in asystole for 25 min.

One of the paramedics took the decision that the best chance of survival for the patient was for quality uninterrupted chest compressions and without a mechanical device they did not feel this was achievable while travelling at high speed along the country roads. When they positioned him on the LUCAS² device it detected that the patient's anterior posterior chest height was below the minimum level set (figure 1). In order to increase his chest height, a blanket was rolled underneath his back (figure 2). This allowed the LUCAS pressure

Figure 1 An image to demonstrate that the patient's anterior-posterior chest height was below the minimum level set.

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To cite: Sugarman L, Hedley D, Crowe S. *BMJ Case Rep* Published Online First: [please include Day Month Year]. doi:10.1136/bcr-2017-219728

Figure 2 An image to demonstrate that rolling a blanket under the patient's back increased his anterior–posterior chest height so the LUCAS suction device could create a tight seal on his chest and deliver compliant CPR. CPR, cardiopulmonary resuscitation; LUCAS, Lund University Cardiopulmonary Assist System.

pad to create a tight seal on the patient's chest and thus perform CPR effectively including chest recoil. On route to the hospital, the patient reverted to pulseless electrical activity rhythm and as his cardiac rate climbed, ROSC was achieved. However, output was lost momentarily before arriving at hospital. With further CPR and a total of six doses of adrenaline, the patient had ROSC on arrival at Nobles Hospital. At no point in the journey had there been any regular breathing or signs of life. Overall, the patient was without a pulse for 40 min.

Once he was assessed in hospital, he remained intubated but did begin spontaneously breathing at a rate of 10/min. He was noted to have widespread expiratory wheeze with oxygen saturations of 70%. His recorded blood pressure was 130/90 mm Hg and his ECG showed normal sinus rhythm. His Glasgow Coma Scale remained 3/15 with unresponsive dilated pupils. He was also hypothermic with a temperature of 34.7°C.

INVESTIGATIONS

His initial blood gas showed a severe acidosis with a pH of 6.520, a pCO₂ of 14.76. His initial lactate level was 12.3.

TREATMENT

The treatment initiated in hospital followed the British Thoracic Society guidelines⁴ for the treatment of life-threatening asthma and included the following:

Hydrocortisone 100 mg

Nebulised salbutamol 5 mg

Magnesium Sulfate 1.6 g

Aminophylline intravenous bolus 200 mg, Aminophylline intravenous infusion 200 mg at 30 mL/hour

Salbutamol intravenous bolus 3 mg

Ketamine 40 mg

He also received antibiotics and treatment for his severe acidosis.

Ceftriaxone 2 g

Sodium bicarbonate 8.4% (×3) 20 mL

OUTCOME AND FOLLOW-UP

The patient was transferred to Alder Hey Hospital where he spent many months recovering and undergoing extensive

rehabilitation. He underwent numerous investigations to ascertain the cause of his cardiac arrest which remain largely inconclusive.

There was a suspicion of Long QT syndrome although this was never confirmed but consequently the patient had an implantable cardioverter defibrillator inserted in 2015.

He has an acquired hypoxic brain injury which has left him with parkinsonian symptoms and occasional limb weakness as well as mild dysarthria. However, following extensive rehabilitation, he has now returned to a mainstream school and is able to walk unaided. He has also started playing sport again including football and cricket which he particularly enjoys. He continues to be followed up by the multidisciplinary team of physiotherapists, occupational therapists, speech and language therapists and the paediatricians to further aid his recovery and who strive to bring back some semblance of normality to his life.

Of note, the patient did not sustain any rib or sternum fractures following prolonged use of the LUCAS² device and this can go some way to alleviating the concern of causing significant injury using mechanical CPR devices.

DISCUSSION

According to the manufacturers and following an extensive literature search, this appears to be the first documented case of mechanical CPR being used in the paediatric population. There are no guidelines regarding this likely due to the manufacturers stating that mechanical devices are contraindicated in children.

When reviewing the literature, one must take into account the ethical considerations that arise when undertaking research in medical emergencies especially in a prehospital environment. This is particularly key when involving children where the ethical concerns are numerous particularly with issues regarding consent.

In any case of OHCA, the patient is unable to consent to take part in trials for novel treatment approaches or research and there may not be anyone present to consent on their behalf. This will always be a limitation to developing good quality research under these circumstances. Another ethical consideration regards the principle of beneficence. All treatment pathways should adopt this approach to manage the patient in their best interests. Therefore, it may prove difficult to gain ethical approval for a randomised control trial to test a novel piece of equipment if it means one subset of patients cannot be guaranteed the more favourable treatment option. These ethical issues probably contribute to the relative paucity of literature on OHCA particularly in a paediatric population.

Survival from paediatric OHCA remains extremely low at <10% but there are a few factors identified in the literature linked to improved survival including bystander CPR, early arrival of emergency medical service personnel and early defibrillation.⁵ Clearly in this case, the bystander CPR was crucial as well as very early initiation of ALS.

There is evidence such as the LINC Randomised control trial⁶ that compares mechanical CPR with the standard approach and while the evidence does not show a massive improvement with mechanical CPR, findings in the literature relating to the physiological differences in the two methods provide interesting reading.

A systematic review of 10 studies was carried out to compare the efficacy of manual CPR versus mechanical CPR during transport of the patient in different vehicles.⁷ A study by Stapleton⁸ demonstrated that mechanical CPR was able to provide compliant compressions in 97% of the transfers compared with 37% when

manual CPR was performed. A further study by Sunde *et al*⁹ found that an increase in weak compressions was demonstrated during ambulance transfer for the group performing manual CPR.

Furthermore, one study found that with manual CPR, the hands-off ratio increased from 0.19 ± 0.09 on-scene to 0.27 ± 0.15 ($p=0.002$) during transport.¹⁰

Manual chest compressions provide approximately 30% of normal cardiac output and have been noted to be of particularly poor quality when undertaken during patient transport.¹¹

The benefit of the LUCAS device is that it is programmed to administer consistent rate and a compression depth of 5.2 cm and is also the only automated device which uses a suction cup pressure pad to assist the decompression phase by drawing up on the chest and returning it to a neutral position. In doing so, it provides a positive intrathoracic pressure when the chest is compressed and conversely, when the chest wall recoils it creates a small negative pressure, which draws the blood back into the

heart thereby creating preload. These changes in intra-thoracic pressure result in enhanced cardiac output.¹²

In this rare circumstance, the chance of this patient surviving an OHCA was already extremely poor. Although he had early bystander CPR and ALS treatment, he had a 'down-time' of 40 min and a long transfer time to hospital. We feel that the use of mechanical CPR during the transfer to hospital has contributed to a favourable outcome whereby if manual CPR had been attempted the child may have died. The paramedic himself has admitted that he would have found it virtually impossible to carry out effective CPR on the patient with the ambulance travelling at such high speeds on unpredictable country roads. We have an obligation to provide care that gives the patient the highest chance of survival and with ineffective manual CPR in the back of a fast moving vehicle, there is little to no doubt that the patient would not have survived.

We believe that the risk to benefit ratio in this case was more than met with LUCAS and this case demonstrates that using mechanical CPR in a paediatric population in extreme circumstances should be considered.

Patient's perspective

On 23 January, I witnessed my son have an out-of-hospital cardiac arrest. I couldn't bear it seeing my precious son looking so lifeless. It was so traumatic and I was shaking and crying. The paramedics told me that my son was the youngest patient they had ever used the life-saving equipment (LUCAS) on. My son's heart stopped for an hour in total. He was transferred to Alder Hey Hospital and the next few months were such a slow, painstaking process. Everyday my heart breaks and I feel emotionally and physically drained. However, I am also blessed that my miracle fighter son pulled through it all. I stayed at the hospital with him for 75 days and when he was transferred back home, he underwent months of rehabilitation. He has made such incredible progress and I see him as my miracle child. We still have such a long way to go but he is now back at school and trying to lead a normal teenage life with me and his brothers. Without the incredible treatment he received including the use of the LUCAS CPR machine, he would have been probably dead. I am so thankful to everyone who saved him, and I and my son are so pleased to be raising awareness and helping doctors and medical staff to try and save the lives of other children who might benefit from this story and widen the use of mechanical CPR in the child population.

Learning points

- ▶ Mechanical cardiopulmonary resuscitation (CPR) devices in the paediatric population should be considered in extreme circumstances.
- ▶ Mechanical CPR devices can provide better guideline compliant CPR in adults during transport compared with manual CPR.
- ▶ Mechanical CPR devices can protect emergency medical personnel from potential injury sustained while attempting to carry out CPR in a fast moving vehicle.

Contributors LCS: conducted the literature search and wrote the case report. DH: came up with the idea to write the case report and requested the patient perspective from the patient's mother. SC: the paramedic who provided the treatment for the patient and came up with the novel idea to adapt the mechanical CPR device. DH and SC: read the case report and provided feedback on possible edits.

Competing interests None declared.

Patient consent Obtained.

Provenance and peer review Not commissioned; externally peer reviewed.

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