Clinical paper

The analysis of efficacy for AutoPulse™ system in flying helicopter

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A B S T R A C T

Aim of the study: The helicopter emergency medical service (HEMS) was introduced in Japan in 2001, and some cardiopulmonary arrest (CPA) patients are transported using this service. However, it is difficult to maintain continuous and effective manual cardiopulmonary resuscitation (CPR) in flying helicopters. To overcome this problem, the AutoPulse™ system, automated mechanical CPR devices, was induced. We conducted a retrospective study to clarify the efficacy of AutoPulse™ on CPA patients in flying helicopters.

Methods: In total, 92 CPA patients were enrolled in this study. Of these, 43 CPA patients received manual CPR (between April 2004 and June 2008), and 49 patients received AutoPulse™ CPR (between July 2008 and March 2011). We compared the manual CPR group with the AutoPulse™ group using logistic regression analysis and examined the efficacy of AutoPulse™ in flying helicopters.

Results: Rates for return of spontaneous circulation (ROSC) and survival to hospital discharge were increased in the AutoPulse™ group compared to the manual CPR group (ROSC, 30.6% [15 patients] vs. 7.0% [3 patients]; survival to hospital discharge, 6.1% [3 patients] vs. 2.3% [1 patient]). In multivariate analysis, the factors associated with ROSC were the use of AutoPulse™ (odds ratio [OR], 7.22; P = 0.005) and patients aged ≤ 65 years (OR, 0.31; P = 0.042).

Conclusion: The present study demonstrates that the use of AutoPulse™ in flying helicopters was significantly effective for the ROSC in CPA patients. The use of automated chest compression devices such as AutoPulse™ might be recommended at least for CPA patients transported by helicopters.

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1. Introduction

The survival rate of patients suffering from cardiopulmonary arrest (CPA) is related to 5 links of the “chain of survival” concept: early access, early CPR, early defibrillation, early advanced life support, and integrated post-cardiac arrest care.1–3 Previous studies have shown that the survival of out-of-hospital cardiac arrest is more closely associated with prehospital factors such as early CPR and early defibrillation than with in-hospital factors.4–6 Therefore, prehospital emergency care is an important factor in survival. To enable earlier commencement of treatment, helicopters and other aircraft are used in order to carry doctors to the sites of emergency in many countries. The helicopter emergency medical service (HEMS) was introduced in Japan in 2001, and it was referred to as “Doctor Heli” in Japan in order to emphasize that the doctors move rapidly to patients by a helicopter to provide medical device. By March 2011, 26 helicopters had been deployed in 22 prefectures across Japan.

Our hospital is responsible for the eastern region of Shizuoka Prefecture, including the Izu Peninsula (Fig. 1). This region, approximately 4090 km² in area with a population of approximately 2 million, is mountainous with only a few hospitals. In order to reduce hospital transport times using ambulances, HEMS was initiated in 2004 with Juntendo University Shizuoka Hospital serving as the base hospital. The journey from the southern tip of the peninsula to the Critical Care Medical Center of our hospital takes a 2 h by ambulance, but only 15 min by helicopter. Currently, most CPA patients are carried using this HEMS.

In cases of CPA, continuous manual CPR must be administered during the transport of patients by helicopter.7 However, this raises several difficulties in terms of effective chest compression. Because the limited space are available in helicopters for medical devices and medical staff, incorrect compression rates or depths and frequent interruptions may occurred during transporting CPA patients by helicopter.8–11 Therefore, it is difficult to administer continuous and effective CPR inside a helicopter.12,13 Incorrect chest
compression results in poor return of spontaneous circulation (ROSC), and any interruption to chest compression generated blood flow is detrimental.\textsuperscript{14-17} To overcome these problems, we introduced the AutoPulse\textsuperscript{TM} system (ZOLL Circulation, Sunnyvale, CA), which is automated mechanical CPR devices.

According to the American Heart Association (AHA) Guidelines 2010, AutoPulse\textsuperscript{TM} CPR is classified into Class IIIb of the Evidence Levels.\textsuperscript{1} Some studies have found improved hemodynamics and ROSC with the use of AutoPulse\textsuperscript{TM} on CPA patients.\textsuperscript{18-21} while others showed a negative neurological outcome.\textsuperscript{22} This means that there is insufficient evidence regarding the efficacy of automated chest compression devices. To our knowledge, there are no previous studies analyzing CPR supplemented with an automated chest compression device on CPA patients in helicopters. Therefore, we conducted a retrospective study to establish the efficacy of AutoPulse\textsuperscript{TM} CPR on CPA patients compared with that of manual CPR only during helicopter transport.

2. Methods

2.1. Patients’ characteristics

A total of 205 CPA-related patients between April 2004 and March 2011 were enrolled in the study. Between April 2004 and June 2008, there were 93 CPA-related patients. Among these, we excluded cases involving hopeless resuscitation, transportation by ambulance, and spontaneous circulation return before arrival at the scene. The hopeless resuscitation defined the presence of obvious evidence that clearly indicates irreversible death such as rigor mortis or dependent livido according to Utstein style.\textsuperscript{23} The remaining 43 patients constituted the manual CPR group. These CPA patients received manual CPR inside the helicopter during transports, essentially from a doctor and a nurse. Between July 2008 and March 2011, there were 112 CPA-related patients. We again excluded cases involving hopeless resuscitation, transportation by ambulances, no application of AutoPulse\textsuperscript{TM} due to external chest wound and small children. The remaining 49 patients were constituted the AutoPulse\textsuperscript{TM} group (Fig. 2).

This study was approved by the Ethics Committee of Juntendo University Shizuoka Hospital in accordance with the Declaration of Helsinki.

2.2. Helicopter: specifications

The EC145 (BK117) type helicopter is 13.00 m long, 11.00 m wide, and 3.85 m high with a maximum takeoff weight of 3350 kg and an effective payload of 1586 kg. Its cruise range is 550 km with a cruise duration of 2.5 h. It accommodates 7 passengers: a pilot, mechanic, doctor, nurse and patient with room for 2 others.

2.3. AutoPulse\textsuperscript{TM}

AutoPulse\textsuperscript{TM} is an automated, portable, battery-powered cardiopulmonary resuscitation device. It contains a control computer, a rechargeable battery and the motors that operate the LifeBand. The LifeBand pulls tight around the chest, determines the patient’s chest size and resistance, and proceeds to rhythmically constrict the entire rib cage. The AutoPulse\textsuperscript{TM} weighs 9.71 kg and is 462 mm wide, 84 mm high and 825 mm deep. The helicopter is always equipped with AutoPulse\textsuperscript{TM}.

We used AutoPulse\textsuperscript{TM} along with manual CPR after July 2008. AutoPulse\textsuperscript{TM} was placed on the helicopter stretcher, and we attached the device to the patient after the patient was placed on the stretcher. Chest compression was continued until ROSC or arrival at the Emergency Room (ER). When CPA patients arrived at the ER, we switched from AutoPulse\textsuperscript{TM} CPR to manual CPR. Manual CPR in the ER was conducted according to the AHA Guidelines 2005.

2.4. Measurements

The following measured data was collected according to Utstein style:\textsuperscript{23} patients’ age and gender, etiology of CPA (cardiac/non-cardiac and endogenous/exogenous), witnesses (presence/absence), availability of bystander CPR, time lapse between CPA perception to paramedics’ arrival, time lapse between paramedics’ arrival and doctor’s arrival, time of manual CPR application, time of AutoPulse\textsuperscript{TM} application, initial cardiac arrest rhythm, result of ROSC, and outcome at the time of patient’s release from hospital. Cardiac etiology included presumed cases. Endogenous etiology defined a disease that came from within the human body as opposed to being caused by something externally, such as aortic dissection, pulmonary thromboembolism, pneumonia. Clinical outcome were neurologically assessed according to the Glasgow Pittsburgh Overall Performance Categories.\textsuperscript{23,24}

2.5. Statistical analysis

We conducted statistical analyses using IBM SPSS 13.0 (IBM SPSS, Chicago, IL, USA). In the univariate analysis, the Mann–Whitney U-test was used for continuous variables between the 2 groups, and the Chi-squared test was used to compare qualitative data. In the multivariate analysis, logistic regression analysis was performed to identify the factor associated with circulation return. A P-value <0.05 was considered statistically significant in all analyses.

3. Results

3.1. Patients’ characteristics

The characteristics of 92 patients (manual CPR group, N=43; AutoPulse\textsuperscript{TM} group, N=49) are summarized in Table 1. There were no significant differences between the 2 groups. The median age was 65 years in the manual CPR group, and 71 years in the AutoPulse\textsuperscript{TM} group. In the manual CPR group, the etiology of CPA was cardiac in 16 cases and non-cardiac in 27 cases. Among 27 patients with non-cardiac CPA, 7 cases involved an endogenous etiology, and 20 involved an exogenous etiology (14 cases of trauma and 6 cases of drowning) (Table 2). In the AutoPulse\textsuperscript{TM} group, the etiology of CPA was cardiac in 21 cases and non-cardiac in 28 cases.
Among 28 patients with non-cardiac CPA, there were 7 endogenous cases and 21 exogenous cases (12 cases of trauma, 7 cases of drowning, 1 case of suicide, and 1 case of suffocation).

Among CPA patients in the manual CPR group, 7.0% (3 of 43) had successful circulation return. In contrast, 30.6% of patients (15 of 49) in the AutoPulse™ group had successful circulation return ($P=0.007$).

In the manual CPR group, 3 patients had successful circulation return and only 1 patient survived. The Glasgow Pittsburgh Overall Performance Categories (OPC): OPC1: no or mild neurological disability, 1 case, and was discharged. In the AutoPulse™ group, 15 patients had successful circulation return, and there were 3 survival patients (OPC1, 2 cases; OPC3: severe neurological disability, 1 case), who were discharged. Clinical backgrounds of these survival patients were summarized in Supplementary Table 1. All survivors were characterized by male gender, presence of witness and bystander CPR.

Supplementary material related to this article found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2013.01.014.

### Table 1

<table>
<thead>
<tr>
<th></th>
<th>Manual CPR</th>
<th>AutoPulse™</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cases</td>
<td>43</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>Age (years)$^a$</td>
<td>65 (26–92)</td>
<td>71 (15–87)</td>
<td>0.372</td>
</tr>
<tr>
<td>Gender (male/female)$^b$</td>
<td>31/12</td>
<td>38/11</td>
<td>0.632</td>
</tr>
<tr>
<td>Etiology (endogenous/exogenous)$^b$</td>
<td>23/20</td>
<td>28/21</td>
<td>0.834</td>
</tr>
<tr>
<td>Etiology (cardiac/non-cardiac)</td>
<td>16/27</td>
<td>21/28</td>
<td>0.672</td>
</tr>
<tr>
<td>Witnesses (absence/presence)$^b$</td>
<td>12/31</td>
<td>24/25</td>
<td>0.054</td>
</tr>
<tr>
<td>Bystander CPR (absence/presence)$^b$</td>
<td>25/18</td>
<td>25/24</td>
<td>0.534</td>
</tr>
<tr>
<td>Emergency perception-paramedics arrival (min)$^a$</td>
<td>13 (3–31)</td>
<td>14 (0–62)</td>
<td>0.459</td>
</tr>
<tr>
<td>Paramedics-helicopter team arrival (min)$^a$</td>
<td>18 (0–49)</td>
<td>19 (0–54)</td>
<td>0.578</td>
</tr>
<tr>
<td>Manual CPR (min)$^a$</td>
<td>53 (10–87)</td>
<td>41 (0–71)</td>
<td>0.001</td>
</tr>
<tr>
<td>AutoPulse™ CPR (min)</td>
<td>--</td>
<td>15 (3–30)</td>
<td></td>
</tr>
<tr>
<td>Cardiac arrest rhythm (VF or VT/PEA/asystole)$^b$</td>
<td>3/11/29</td>
<td>4/8/37</td>
<td>0.549</td>
</tr>
<tr>
<td>Circulation return (success/failed)$^c$</td>
<td>3/40</td>
<td>15/34</td>
<td>0.007</td>
</tr>
<tr>
<td>Outcome (survival/death)$^c$</td>
<td>1/42</td>
<td>3/46</td>
<td>0.620</td>
</tr>
</tbody>
</table>

CPR, cardiopulmonary resuscitation; VF, ventricular fibrillation; VT, ventricular tachycardia; PEA, pulseless electrical activity.

$^a$ Mann–Whitney U test;

$^b$ Chi-square test.

$^c$ Fisher's exact test.

#### 3.2. Factors associated with ROSC

To examine the efficacy of AutoPulse™, we analyzed factors associated with ROSC. In univariate analysis, the duration of manual CPR application ($P=0.016$) and additional use of AutoPulse™ ($P=0.009$) were selected as factors associated with ROSC (Table 2). In multivariate analysis, younger age ($P=0.042$) and additional use of AutoPulse™ ($P=0.005$) were selected as factors associated with ROSC (Table 3).

Fig. 3 illustrates the rate for CPA patients who achieved ROSC according to 4 categories including status of age and use of AutoPulse™. In particular, 47% of patients aged <65 years had ROSC after use of AutoPulse™. It appears that AutoPulse™ is more effective in young CPA patients.

### 4. Discussion

The results of the present study demonstrate that use of the AutoPulse™ system in flying helicopters was effective in CPA...
patients. In fact, the number of patients achieved ROSC was significantly increased after introduction of the AutoPulse™ system.

Our region of Japan is mountainous, and the provision of emergency medical facilities was not sufficient. HEMS is provided in cases of CPA. However, it has always been very difficult to continue effective CPR in flying helicopters. Because helicopters have such limited space, only 2 medical staff are able to board, and free movement in the helicopter is impossible. Therefore, the person who begins chest compression must continue it alone. Incorrect compression rate or depth, as well as frequent interruptions can occur during the transport of CPA patients by helicopter. Therefore, we introduced the AutoPulse™ system in order to resolve

<table>
<thead>
<tr>
<th>Variable</th>
<th>Manual CPR group (N = 43)</th>
<th>AutoPulse™ group (N = 49)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age &lt;65</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>≥65 (years)</td>
<td>0.14–1.18</td>
<td>0.098</td>
<td>0.31 (0.10–0.96)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>0.83 (0.24–2.82)</td>
<td>0.762</td>
<td></td>
</tr>
<tr>
<td>Etiology Cardiogenic</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-cardiogenic</td>
<td>1.98 (0.64–6.13)</td>
<td>0.235</td>
<td></td>
</tr>
<tr>
<td>Witnesses Absence</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence</td>
<td>0.76 (0.27–2.16)</td>
<td>0.607</td>
<td></td>
</tr>
<tr>
<td>Bystander CPR Absence</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence</td>
<td>1.64 (0.58–4.63)</td>
<td>0.35</td>
<td></td>
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<tr>
<td>Emergency perception-Paramedics arrival &lt;10</td>
<td>1</td>
<td>1.02 (0.34–3.04)</td>
<td>0.971</td>
</tr>
<tr>
<td>≥10 (min)</td>
<td>0.84 (0.29–2.40)</td>
<td>0.738</td>
<td></td>
</tr>
<tr>
<td>Paramedics-helicopter team arrival &lt;20</td>
<td>1</td>
<td>0.25 (0.08–0.77)</td>
<td>0.016</td>
</tr>
<tr>
<td>≥20 (min)</td>
<td>3.38 (0.67–17.10)</td>
<td>0.142</td>
<td></td>
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<tr>
<td>Manual CPR &lt;20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥20 (min)</td>
<td>0.84 (0.21–3.36)</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>Cardiac arrest rhythm</td>
<td></td>
<td></td>
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<tr>
<td>Asystole</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEA</td>
<td>5.89 (1.60–22.05)</td>
<td>0.009</td>
<td></td>
</tr>
<tr>
<td>VF or VT</td>
<td>7.22 (1.84–28.40)</td>
<td>0.005</td>
<td></td>
</tr>
</tbody>
</table>
In this study, we assessed the use of AutoPulse™ in flying helicopters. HEMS is requested when CPA occurrence is recognized (for example, in a 1-1-9 call) or based on the paramedics’ judgment upon their arrival at the emergency site. If HEMS has been requested, paramedics continue Basic Life Support (BLS) such as cardiopulmonary resuscitation at the site or in the ambulance until the doctor arrives by helicopter. After the doctor arrives at the emergency site, the doctor initiates Advanced Cardiovascular Life Support (ACLS), including tracheal intubation, intravenous catheterization and medication. If paramedics were able to use AutoPulse™ at the emergency site, the rate for ROSC might be improved further.

Sternum and rib fractures are often encountered during manual CPR. However, severe injuries such as liver rupture or rib fracture were not observed in the present study. Previous studies also reported no occurrence of severe injury while using AutoPulse™, 18,20,22 according to the device’s manual, some superficial skin abrasion was observed but only when it was used for a long period of time. Thus, the use of AutoPulse™ appears to be safe. Finally, although the efficacy and safety of AutoPulse™ in flying helicopters is clear, its routine use raises various problems. First, the AutoPulse™ system is designed for adults and cannot be used for pediatric patients. Second, it is necessary to undergo training for appropriate use of AutoPulse™. Following training, it takes approximately 30 s to attach the AutoPulse™. Third, a completely charged battery runs for a maximum of 30 min. Finally, the AutoPulse™ system is expensive.

5. Conclusions

In conclusion, our results demonstrated that the use of AutoPulse™ in flying helicopters was significantly effective among CPA patients: the use of automated chest compression devices such as AutoPulse™ inside helicopters improves ROSC and survival. However, further studies including larger or prospective randomized studies are required to clarify the efficacy of the AutoPulse™ system.

Conflict of interest

The authors declared that they do not have anything to disclose regarding funding or conflict of interest with respect to this manuscript.

Acknowledgement

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References


Fig. 3. The rates for the ROSC according to the status of age and use of AutoPulse™. It shows that AutoPulse™ is most effective in CPA patients aged ≤65 years. ROSC, return of spontaneous circulation; CPA, cardiopulmonary arrest.