Resuscitation (2008) **77**, 374—378

available at www.sciencedirect.com

journal homepage: www.elsevier.com/locate/resuscitation

CLINICAL PAPER

Alteration in transthoracic impedance following cardiac surgery

Nouman U. Khan*, Tim Strang, Claire Bonsheck, Bhuvana Krishnamurty, Timothy L. Hooper

Department of Cardiothoracic surgery and Anaesthesia, University Hospital of South Manchester NHS Foundation Trust, Wythenshawe Hospital, Southmoor Road, Manchester M23 9LT, United Kingdom

Received 6 August 2007; received in revised form 28 January 2008; accepted 1 February 2008

KEYWORDS
Defibrillation;
Resuscitation;
Transthoracic impedance;
Cardiac surgery

Summary
Introduction: Haemodynamically significant ventricular tachyarrhythmias are a frequent complication in the immediate post-operative period after cardiac surgery. Successful cardioversion depends on delivery of sufficient current, which in turn is dependent on transthoracic impedance (TTI). However, it is uncertain if there is a change in TTI immediately following cardiac surgery using cardiopulmonary bypass (CPB).
Methods: TTI was measured on 40 patients undergoing first time isolated cardiac surgery using CPB. TTI was recorded at 30 kHz using Bodystat® Multiscan 5000 equipment before operation (with and without a positive end-expiratory pressure (PEEP) of 5 cm of H_2O) and then at 1, 4 and 24 h after the operation. Data was analyzed to determine the relationship between pre- and post-operative variables and TTI values.
Results: Mean pre-operative TTI was $54.5 \pm 10.55\,\Omega$ without PEEP and $61.8 \pm 15.4\,\Omega$ on a PEEP of 5 cm of H_2O. TTI dropped significantly ($p < 0.001$) after the operation to $47.2 \pm 10.6\,\Omega$ at 1 h, $42.6 \pm 10.2\,\Omega$ at 4 h and $41.8 \pm 10.4\,\Omega$ at 24 h. A positive correlation was noted between duration of operation and TTI change at 1 h ($r = 0.38$; $p = 0.016$). There was no significant correlation between the duration of bypass and change in TTI.
Conclusion: TTI decreases by more than 30% in the immediate post-operative period following cardiac surgery. This state may favour defibrillation at lower energy levels.

Introduction

A cardiac arrest following cardiac surgery is not an uncommon event, with an incidence of approximately 0.5—2% in the immediate post-operative period.[1–3] Electrical cardioversion is necessary to terminate ventricular fibrillation/pulse less ventricular tachycardia. Successful electrical cardioversion by transthoracic defibrillation is

* Corresponding author. Tel.: +44 161 291 2092; fax: +44 161 291 2091.
E-mail address: n_u_khan@hotmail.com (N.U. Khan).

0300-9572/$ — see front matter
doi:10.1016/j.resuscitation.2008.02.003

dependent upon delivery of sufficient current through the heart to depolarize a critical mass of myocardium.[4] While weak defibrillation shocks are likely to fail, sufficiently strong defibrillation shocks can cause temporary or permanent damage to the heart.[5,6] Therefore, any factor affecting trans-myocardial current may have an adverse effect on the success of defibrillation. The current resuscitation guidelines from the European Resuscitation Council have increased the energy settings for defibrillation following cardiac surgery. According to these guidelines, the energy level for the first shock has been increased from 200 to 360 J monophasic shock (150—200 J biphasic).[7]

Current flow during cardioversion is determined by the operator-selected electrical energy (J) and the impedance or resistance (Ω). Current is related to these two factors by the equation: $\mathrm{Im} \alpha \sqrt{E}/Z$, where Im is the peak discharge current; Z is the impedance and E the electrical energy selected.[8] It is documented that transthoracic impedance (TTI) is an important factor determining trans-myocardial current.[9,10] While high impedance alters monophasic defibrillation waveforms, impedance compensatory mechanisms have been incorporated in the newer biphasic defibrillators.[11]

Cardiac surgery is routinely performed with cardiopulmonary bypass (CPB), which initiates an inflammatory response.[12] It results in capillary fluid leak secondary to haemodilution, inflammation and hypothermia.[13] There is evidence that increases in tissue blood volume contributes to a decline in TTI.[14] However, it is not known whether CPB has any immediate impact on TTI. A previous study that compared pre-operative TTI to the values taken 3—5 days following median sternotomy showed a decline in TTI. They, however, did not perform TTI measurements within the first 24 h following cardiac surgery.[15] We hypothesize that TTI will reduce within the first 24 h after cardiac surgery using CPB.

Methods

Study patients

Following Local Research Ethics Committee approval, 44 patients undergoing first time cardiac surgery were recruited. The power of the study was calculated using the specialist sample size statistical software package nQuery Advisor® Version 6.0. According to the power calculation, a sample size of 44 would have 90% power to detect difference of 0.5 S.D. or more in the change of TTI before and after bypass (assuming a simple paired *t*-test is used with the conventional 5% significance level). This relates to a difference of 3.5 Ω, using an estimate of S.D. of differences = 7 Ω, as used in a previous study.[16] Written informed consent was obtained from all the patients. All patients had routine shaving of hairs from the chest before surgery. The anaesthetic and operative techniques, including the use of CPB was according to the already set standardized protocol. CPB was carried out with moderate haemodilution (haematocrit 22—25%) and either moderate hypothermia (30—32 °C) or normothermia, depending on surgeons' preference. All patients were fully rewarmed before the end of the procedure.

Measurement of transthoracic impedance

TTI was measured using Bodystat® Multiscan 5000 impedance measuring equipment (Bodystat Ltd., Isle of Man, UK) as performed in previous studies.[15,17] Measurement was averaged over a 5-s period using a low current sinusoidal wave at 30 kHz. Self-adhesive electrodes (Bodystat®) were placed in the anterior-apical position, according to the current guidelines of the European Resuscitation Council.[16] Anterior electrodes were placed to the right of the upper part of sternum, just below the right clavicle. The apical electrodes were placed over the left 5th intercostal space in the left midaxillary line, in a position corresponding to the cardiac apex. Measurement of TTI is imperceptible by the patient.

TTI was measured twice before the operation, first with the awake patient (at end-expiration while breath was held), and then on the ventilated patient with a positive end-expiratory pressure (PEEP) of 5 cm of H_2O.

Three further measurements of TTI were obtained after the completion of the operation; first, 1 h after patient returned to the intensive care unit, second, 3 h later and then another one 24 h after the operation. All the measurements were performed at end-expiration.

The data from four patients could not be used due to inaccurate placements of electrodes and improper use of the impedance measuring device (in three) and concurrent pacing in one patient. Therefore, analysis was performed using data from 40 patients.

Other recorded variables

Demographic and operative details were recorded for each patient. Along with each reading of TTI, some more variables were also recorded to account for any possible correlation with the change in TTI. These included temperature, fluid balance and total use of crystalloids and colloids. Post-operative body weight could not be recorded due to logistical issues and possible inaccuracy in measurements.

Statistical analysis

Data were analyzed using SPSS v.11. Mean values ± S.D. were calculated at each time point. Means were compared using the Student's paired *t*-test and repeated measures ANOVA. Pearson correlation analyses were used to determine the correlation between pre- and post-operative variables and TTI values. A p value of <0.05 was considered statistically significant.

Results

The data from 40 patients was included in the study. The demographic and operative data are as in Table 1.

TTI values showed a statistically significant drop from pre-operative to post-operative values (with or without PEEP) at all intervals ($p < 0.001$). (Table 2).

The continuing linear downward trend in TTI from pre-operative to post-operative values was also of high significance ($p < 0.001$) (repeated measures ANOVA) (Figure 1).