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Effect of General Anesthesia on the Defibrillation Energy Requirement in Patients Undergoing Defibrillator Implantation

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Abstract. Background: **The effect of general anesthesia on defibrillation efficacy in humans is not known. The purpose of this study was to determine the effect of general anesthesia on the defibrillation energy requirements in patients undergoing implantation of a pectoral defibrillator.**

Methods and Results: **Nineteen consecutive patients who underwent defibrillator implantation under general anesthesia were prospectively compared to 16 consecutive patients who underwent defibrillator implantation by the same physicians, using similar devices, at another hospital under conscious sedation. Pre-discharge testing was performed 1.4 ± 1.0 days after implant using sedation in both groups. The defibrillation energy requirement was determined using the same predefined step-down protocol (15, 10, 8, 5, 3, 1 J) at the time of implantation and during pre-discharge testing. The clinical characteristics of the patients were similar between groups. There was no significant difference in the mean implant defibrillation energy requirement compared to the mean pre-discharge defibrillation energy requirement in either the general anesthesia group (8.5 ± 4.7 vs. 8.4 ± 3.4 J; p = 0.9) or in the conscious sedation group (9.4 ± 3.9 vs. 9.0 ± 3.8 J; p = 0.7).**

Conclusions: **When compared to conscious sedation, general anesthesia with mechanical ventilation has no significant effect on defibrillation efficacy in patients undergoing defibrillator implantation.**

Key Words. **anesthesia, defibrillation**

Nonthoracotomy defibrillator implantation is performed using either general anesthesia or conscious sedation combined with local anesthesia [1–5]. No study has determined the independent effect of general anesthesia on defibrillation efficacy in humans. Therefore, the purpose of this study was to compare the effects of general anesthesia and conscious sedation on the defibrillation energy requirements in patients undergoing implantation of a defibrillator.

Methods

Study design

Defibrillators were implanted at one hospital in the operating room and at another hospital in the electrophysiology laboratory by the same electrophysiologists. At the hospital where implants were performed in the operating room, there was a transition period after pectoral defibrillators became available, during which time general anesthesia remained the preferred approach by the anesthesiologists. At the other hospital, pectoral defibrillators were implanted using conscious sedation combined with local anesthesia in the electrophysiology laboratory. Pre-discharge defibrillator testing was performed at both hospitals in the same fashion in the electrophysiology laboratory using sedation. The different anesthesia practices at the two hospitals allowed a concurrent comparison of the effect of the two different types of anesthesia on the defibrillation energy requirement.

Study patients

The study population consisted of 19 consecutive patients who underwent implantation of a nonthoracotomy defibrillator under general anesthesia at one hospital and 16 consecutive patients who underwent nonthoracotomy defibrillator implantation under sedation at another hospital during 1997. There were fewer women in the general anesthesia group compared to the conscious sedation group (1/19 vs. 5/16; p = 0.04). Patients in the general anesthesia group tended to have a higher left ventricular ejection fraction than patients in the conscious sedation group (0.33 ± 0.18

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vs. 0.26 ± 0.11, p = 0.2), but this difference did not reach statistical significance. Otherwise, there were no significant differences in the clinical characteristics of the patients in each group (Table 1).

Implantable defibrillator systems

The implanted defibrillator systems were similar in both groups. Patients underwent placement of a dual-coil defibrillation lead (Guidant, Inc., St. Paul, MN; model 125) via the subclavian or cephalic vein into the right ventricular apex, and a defibrillator with a biphasic waveform. The defibrillator shell served as a shocking electrode (Guidant, Inc.; models 1742, 1762, and 1763) in each implanted device, except in one patient in the general anesthesia group (Guidant, Inc.; model 1740) and in one patient in the conscious sedation group (Guidant, Inc.; model 1741). All devices were implanted in the left prepectoral region. One patient in the conscious sedation group also required placement of a subcutaneous array at the time of implantation because of elevated defibrillation energy requirements. There were no implant-related complications.

Testing of defibrillation energy requirements

A predetermined step-down protocol was used to determine the defibrillation energy requirement, at the time of implantation and during pre-discharge testing. Ventricular fibrillation was induced through the device using 50-Hz ventricular pacing, and the defibrillation energy requirement was determined by delivering the following energy steps every 5 minutes: 15, 10, 8, 6, 5, 3, and 1 Joules. The defibrillation energy requirement was defined as the lowest energy that resulted in successful defibrillation. Standard waveform polarity was used initially, where the distal coil is negative, and both the proximal coil and defibrillator shell are positive. If 15 joules initially failed to defibrillate, then the polarity was reversed [6–7] and step-down testing began again at 20 joules. Pre-discharge defibrillator testing was performed using the same polarity.

Table 1. *Baseline characteristics according to study group*

	Type of Anesthesia		
	General	Conscious sedation	p-value
Number	19	16	—
Age (years)	67 ± 10	63 ± 9	0.3
Male/Female	18/1	11/5	0.04
CAD	68%	69%	1.0
LVEF	0.33 ± 0.18	0.26 ± 0.11	0.2
Amiodarone	21%	25%	0.8

Abbreviations: CAD, coronary artery disease; LVEF, left ventricular ejection fraction.

Anesthesia

A combination of different agents was used to achieve surgical levels of anesthesia in the 19 patients who underwent implantation under general anesthesia. After anesthesia induction, each patient underwent tracheal intubation and mechanical ventilation. Intravenous medications used included diazepam (5 patients; 9.0 ± 4.2 mg), midazolam (2 patients; 1.8 ± 0.4 mg), fentanyl (17 patients; 228 ± 98 mcg), remifentanil (1 patient; 50 mcg), propofol (2 patients; 135 ± 163 mg), sodium thiopental (7 patients; 288 ± 157 mg), etomidate (12 patients; 17.5 ± 8.0 mg), cisatracurium (13 patients; 15.7 ± 9.8 mg), succinylcholine (2 patients; 100 ± 0 mg), and pancuronium (3 patients; 6.3 ± 1.5 mg). To achieve a balanced anesthetic technique, patients were also maintained on nitrous oxide (50/50 nitrous oxygen mixture) and/or isoflurane (1 Minimal Alveolar Concentration). Vasopressors were used as needed to maintain arterial blood pressure and included ephedrine (6 patients; 23 ± 18 mg) and phenylephrine (5 patients; 170 ± 140 mcg). Supplemental oxygen was administered.

The 16 patients who underwent implantation under sedation were managed with local anesthesia and conscious sedation throughout the procedure. A combination of 1% lidocaine and 1% bupivacaine was infiltrated subcutaneously. Intravenous medications used included midazolam (16 patients; 6.3 ± 4.1 mg), fentanyl (15 patients; 177 ± 93 mcg), brevital (8 patients; 104 ± 43 mg), and propofol (6 patients; 312 ± 274 mg). Sedation was deepened briefly during defibrillation testing.

Sedation during pre-discharge defibrillation energy requirement testing was performed in the same fashion in each group using a combination of fentanyl (101 ± 44 mcg in the general anesthesia group and 105 ± 55 mcg in the conscious sedation group) and midazolam (10.3 ± 3.0 mg in the general anesthesia group and 10.1 ± 4.8 mg in the conscious sedation group).

Data analysis

All continuous variables were expressed as mean ± standard deviation. A Student's t-test was used to compare continuous variables between groups. A paired t-test was used to compare the defibrillation energy requirements from implantation to pre-discharge within each group. The power to detect a difference of 2.5 Joules within the general anesthesia group was 80%. Chi-square analysis or Fisher's Exact test was used to compare nominal variables. A p-value of 0.05 was considered significant.

Results

The results are shown in Table 2. The duration of anesthesia at the time of defibrillator implantation was longer for patients who received general anesthesia compared to sedation (148 ± 40 vs. 119 ± 40 mins; p = 0.04). The time from implantation to pre-discharge

Table 2. *Results of defibrillation energy requirement testing according to study group*

	Type of Anesthesia		
	General	Conscious sedation	p-value
Duration of anesthesia (mins)	148 ± 40	119 ± 40	0.04
Time between testing (days)	1.2 ± 0.6	1.5 ± 1.3	0.4
Implant DER (J)	8.5 ± 4.7	9.4 ± 3.9	0.5
Pre-discharge DER (J)	8.4 ± 3.4	9.0 ± 3.8	0.6

Abbreviations: DER, defibrillation energy requirement; J, Joules; mins, minutes.

testing was 1.2 ± 0.6 days in the general anesthesia group compared to 1.5 ± 1.3 days in the conscious sedation group (p = 0.4). Patients who received fentanyl in the general anesthesia group received a significantly higher dose of fentanyl compared to patients in the conscious sedation group (243 ± 78 vs. 177 ± 93 mcg; p = 0.04).

There was no significant difference in the mean implant defibrillation energy requirement compared to the mean pre-discharge defibrillation energy requirement in either the general anesthesia group (8.5 ± 4.7 vs. 8.4 ± 3.4 J; p = 0.9) or in the conscious sedation group (9.4 ± 3.9 vs. 9.0 ± 3.8 J; p = 0.7). When patients who received general anesthesia were compared to those who received conscious sedation, there was no difference in the mean implant defibrillation energy requirement (8.5 ± 4.7 vs. 9.4 ± 3.9 J; p = 0.5) or in the mean pre-discharge defibrillation energy requirement (8.4 ± 3.4 vs. 9.0 ± 3.8 J; p = 0.6).

Discussion

Main findings

The main finding of this study is that general anesthesia has no significant effect on the defibrillation energy requirement in patients undergoing defibrillator implantation, when compared to conscious sedation. Defibrillation energy requirements may change after implantation due to changes in lead position [8], lead maturation [9], or changes in clinical status. Studies that demonstrate no change in defibrillation energy requirements from the time of implantation to pre-discharge testing [10–11] have not excluded an effect of anesthesia, because various factors may have opposing influences on the defibrillation energy requirement. The present study controlled for these other factors so that the effects of general anesthesia could be evaluated.

Potential anesthetic effects

The findings of this study do not exclude a balanced net effect of general anesthesia on defibrillation efficacy. It is possible that various factors related to general anesthesia have opposing influences. The direct hemodynamic and electrophysiologic effects of many general anesthetics on the heart [12–13] might have a direct effect on defibrillation energy requirements. In addition, vasopressors, which are often required to counteract the vasodilating effects of general anesthetics, have been shown to increase defibrillation energy requirements in animals [14]. Furthermore, positive-pressure ventilation might influence defibrillation efficacy by changing transthoracic impedance [15]. Changes in transthoracic impedance could have a greater effect on the defibrillation efficacy of active-can pectoral defibrillators [16], where the defibrillator shell serves as a subcutaneous electrode.

Prior studies

No prior published study has evaluated the effect of general anesthesia on defibrillation efficacy in humans. A previous study compared defibrillation efficacy using spring-patch electrodes and monophasic shocks in dogs with 3 different anesthetic techniques [17]. There were no differences when pentobarbital was used, compared to sodium brevital maintained with halothane gas, and sodium brevital maintained with isoflurane gas. Another study in dogs found that defibrillation energy requirements remained stable over a 10-hour period of anesthesia with pentobarbital [18].

Animal studies suggest that lidocaine significantly elevates epicardial defibrillation energy requirements [19–20]. Lidocaine may increase energy requirements in a dose-dependent fashion [21], although very high doses have a minimal effect [22]. The increase in defibrillation energy requirements by lidocaine has also been demonstrated in humans [23]. However, lidocaine may have no effect when biphasic waveforms are used [24]. Furthermore, a recent study in pigs found that although lidocaine (10 mg/kg/hour) increases the defibrillation energy requirement by 59% during epicardial defibrillation, it has no effect during endocardial defibrillation [25].

Limitations

The present study did not standardize the general anesthesia technique. Because various drug combinations were used, an effect on defibrillation efficacy by a specific anesthetic agent cannot be excluded. However, the purpose of this study was to evaluate the overall net effects of general anesthesia on defibrillation, rather than the effects of individual agents.

Another limitation of the study is that there were fewer women in the general anesthesia group compared to the conscious sedation group. However, the gender imbalance occurred most likely by chance and probably did not affect the results of the study [26].

Clinical implications

Although pectoral defibrillators can safely and effectively be implanted by cardiologists in the electro-

physiology laboratory using sedation [1–5], many centers continue to implant defibrillators in the traditional surgical environment using general anesthesia. This study demonstrates that when general anesthesia is used instead of conscious sedation, there is no significant effect on defibrillation efficacy in patients undergoing pectoral defibrillator implantation. Therefore, the type of anesthesia used does not affect comparisons of defibrillation energy requirements between different defibrillation systems.

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