Ultrasound-guided intermuscular pocket creation for a subcutaneous implantable cardioverter-defibrillator

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Introduction

Subcutaneous implantable cardioverter-defibrillators (S-ICDs) are a safe and effective device for prevention of sudden cardiac death.1 Thus, the S-ICD was developed as an alternative therapy to a transvenous ICD (TV-ICD) in patients without an indication of bradycardia or antitachycardia pacing. Compared to the TV-ICD, the defibrillation threshold of the S-ICD is thought to be higher because both the lead and pulse generator are located outside the thorax. In actuality, the maximum delivery energy is set at a value of 80 J. However, the ideal position of the lead and generator is associated with an effective defibrillation. Based on previous reports, a more dorsal pocket position is preferred because there is less tissue between the chest wall and generator.2,3 An intermuscular implantation technique implanting the device between the latissimus dorsi muscles (LDM) and serratus anterior muscles (SAM) achieves this position and improves the cosmetic concern.4,5 Generally, the position of the lead and pulse generator is determined by fluoroscopy and a subcutaneous incision line is planned to be placed at an inframammary site around the midaxillary line based on each physician’s experience. Because the location of the muscles differs among patients, an incision determined based on these methods is not always adequate, and an inappropriate incision line would make it difficult to find the muscles and their border. On the other hand, the preoperative recognition of the location of the muscles can make it easier to find the muscles and their border. In this paper, we report a method of an ultrasound-guided creation of the intermuscular pocket for an S-ICD.

Methods

At the beginning of the procedure while the patient was in the supine position with the ipsilateral upper limb abducted at 90°, the position of the lead and pulse generator was determined by fluoroscopy (step 1). A nonfunctional demonstration device was placed at the level of the fifth to sixth intercostal space at a site more dorsal to the midaxillary line. The lead and generator positions were set to cover the heart silhouette between the shock coil and pulse generator (step 2). A high-frequency (11 MHz) linear ultrasound probe (12L-RS; GE Healthcare) was placed at the fifth to eighth rib level of the left side on the midaxillary line along the axial plane to delineate the LDM and SAM, and the anterior border of the LDM was marked (Figure 1C1 and 1C2) (step 3). When the LDM disappeared on the marked line, we moved the probe from posterior to anterior (Figure 1C3 and 1C4). When the LDM disappeared on the marked line, we determined that the marked line was the anterior border of the LDM (step 4). We could confirm that the upper edge of the pocket set in step 1 was below the anterior border of the LDM (Figure 2A). The cephalic end of the incision line (green arrow in Figure 2A) was placed on the anterior border of the LDM (orange dotted line) and at a finger-breadth distance caudal to the cephalic end line of the S-ICD pocket (blue dotted line) (step 5). The incision was slightly curved for up to 6–7 cm length (Figure 2A), which corresponded to the short-side length of the S-ICD generator (69.1 × 83.2 × 12.7 mm).

KEYWORDS
Cosmetic; Defibrillation threshold; Intermuscular implantation; Latissimus dorsi muscle; Pocket; Serratus anterior muscle; Subcutaneous implantable cardioverter-defibrillator; Sudden cardiac death; Ultrasound; Ventricular fibrillation

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Conflicts of Interest: The Section of Arrhythmia is supported by an endowment from Abbott JAPAN and Medtronic JAPAN. Ken-ichi Hirata chairs the Section, and Koji Fukuzawa belongs to the Section. Koji Fukuzawa does joint research with Biotronik JAPAN and Advantest, and received an endowment from Biotronik JAPAN. However, all authors report no conflict of interest for this manuscript’s content. Address reprint requests and correspondence: Dr Koji Fukuzawa, Section of Arrhythmia, Division of Cardiovascular Medicine, Department of Internal Medicine, Kobe University Graduate School of Medicine, 7-5-2, Chuoh-Ku, Kobe, Japan. E-mail address: kfuku@med.kobe-u.ac.jp.
KEY TEACHING POINTS

- An intermuscular implantation technique implanting the device between the latissimus dorsi muscle (LDM) and serratus anterior muscles (SAM) may improve the defibrillation threshold and the cosmetic concern. For an intermuscular implantation, the boundary between the LDM and SAM needed to be identified.
- Ultrasound would be helpful to distinguish the LDM and SAM clearly and could recognize the change in the fiber pathway as horizontal vs vertical, which was essential for distinguishing the 2 muscles.
- This technique enabled us to identify the anterior border of the LDM within a short distance from the incision line and facilitate the creation of the intermuscular pocket.
- The ultrasound-guided intermuscular identification is considered to be more accurate than the computed tomography image because the evaluation can be performed in the position used during surgery. In addition, this technique needs no fluoroscopy.

Case report
The ultrasound-guided S-ICD implantation was performed in 2 consecutive cases.

The patient background and outcomes are presented in Table 1, and among them, the details of the second case are described. A 27-year-old man with recurrent syncope had a type I Brugada electrocardiogram. His left ventricular function was within normal range (left ventricular ejection fraction = 61%) and he did not need pacing. He passed the S-ICD electrocardiogram screening. Before the procedure, the pocket incision line was marked by ultrasound as described in the methods section. We could clearly distinguish the LDM and SAM (Figure 1C) and could recognize the change in the fiber pathway as horizontal vs vertical, which was essential for distinguishing the 2 muscles. We marked the anterior border of the LDM and the incision line (Figure 2A). When we actually incised the cutaneous layer and cut the subcutaneous tissue, we could detect the 2 muscles and their borders instantly. Further, the anterior border of the LDM was located in the same position as the marked line (Figure 2B), and it could be distinguished from the SAM, which medially had different muscle fibers. Then the pocket was created manually by blunt dissection while the muscle fascia was preserved, which might have minimized the bleeding. We could easily create an intermuscular pocket between the LDM and SAM without any bleeding problems (Figure 2C). The 2-incision technique was performed to place an electrode and generator in the pocket. At the end of the procedure, defibrillation testing was performed. Ventricular fibrillation was induced using a 200 mA alternating current at 50 Hz, and the generator sensed and defibrillated the patient at 40 J successfully without any problems. It took 14.5 and 4.2 seconds from the time it sensed and the time to charge for defibrillation, respectively, and the shock impedance was 53 Ω. The postimplantation posterior-anterior and lateral chest radiographs were analyzed (Figure 3) and the PRAETORIAN score was 30. During the postoperative period, there were no significant complications, including bleeding.

Discussion
For an intermuscular implantation, the boundary between the LDM and SAM needs to be identified. In contrast, the incision line for a conventional S-ICD pulse generator implantation is empirically set near the fifth to sixth intercostal space and midaxillary line. In general, these techniques have been reported with good outcomes and high success rates. However, depending on the positional relationship between the incision line and LDM, it would alter how easy it would be to approach the intermuscular space. For example, if the incision line we drew were too far anterior, there would be more tissue to damage before we reached the intermuscular space. If the line had been above the LDM, the LDM may have been injured and the muscle injury could have led to bleeding. In addition, there are several major blood vessels in the intermuscular space (for example, the thoracodorsal artery and lateral thoracic artery). An optimal incision line placement could reduce the risk of a hematoma by identifying the anterior border of the LDM within a short distance from the incision line and easily create the intermuscular space. Further, several papers have reported that an uninterrupted use of antiagulation and antiplatelet is associated with an increased risk of hematoma. Further, we believe that our ultrasound-guided methods can contribute to reducing the bleeding risk in such patients.

In this paper, the border between the LDM and SAM was delineated by ultrasound, and the incision line was established based on this border. In both cases, the anterior border of the LDM was very easily identified based on this border. In both cases, the anterior border of the LDM was very easily identified just as depicted by the ultrasound, and the pulse generator could be placed in the intermuscular space without any operative complications, including minor bleeding.

The intermuscular space is more dorsal, with less tissue between the chest wall and pulse generator, than the subcutaneous space and would improve the defibrillation threshold. The defibrillation testing is usually conducted by delivering a shock energy of 65 J. However, Biffi and colleagues showed a high rate of defibrillation success with 40 J shocks with S-ICD systems implanted by an intermuscular placement combined with a 2-incision technique. In our
cases, the defibrillation testing was performed and successfully converted each case with a 40 J shock.

The computed tomography image can also assess the positioning of the LDM and SAM, but the patient’s body may elevate or lower during the CT imaging. Since the LDM attaches to the crest of the lesser tubercle of the humerus, the upper limb position affects the position of the muscle. At the time of surgery, the position of the upper limb is abducted, which differs from that for computed tomography imaging. On the other hand, ultrasound-guided intermuscular identification is considered to be more accurate because the evaluation can be performed in the position used during surgery. In addition, this technique is simple and noninvasive, with no fluoroscopy.

Since this was only a report of 2 cases, we were not able to directly compare this technique with the conventional method, nor were we able to examine the long-term outcomes, such as the defibrillation success rate and inappropriate shocks.

Finally, Knops and colleagues reported that there is a significant learning curve associated with physicians adopting the S-ICD, and the precise location of the target muscle and its border is not familiar to all cardiologists. The ultrasound can be performed in real time and noninvasively, without radiation exposure. To find the LDM and SAM

![Figure 1](image-url)
with ultrasound is very easy and any physician can do it. Further, the ultrasound-guided incision placement can facilitate in the intermusculature pocket creation. Therefore, we believe that our methods presented here would help the operator, especially for beginners or inexperienced doctors, to plan and create an appropriate incision line for an intermuscular S-ICD pocket.

### Conclusion

The ultrasound-guided incision determination enabled us to easily and safely create the intermuscular pocket for the S-ICD. The feasibility of the ultrasound-guided S-ICD implantation should be investigated in many patients by many physicians hereafter.

### Table 1

<table>
<thead>
<tr>
<th>Patients’ background and outcomes</th>
<th>Case 1</th>
<th>Case 2</th>
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</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td>Male</td>
<td>Male</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>53</td>
<td>27</td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td>28.4</td>
<td>23.7</td>
</tr>
<tr>
<td><strong>Indication</strong></td>
<td>Secondary prevention</td>
<td>Secondary prevention</td>
</tr>
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<td><strong>Primary cardiac disease</strong></td>
<td>Idiopathic VF</td>
<td>Brugada syndrome</td>
</tr>
<tr>
<td><strong>LVEF</strong></td>
<td>53%</td>
<td>61%</td>
</tr>
<tr>
<td><strong>Defibrillation testing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shock energy</td>
<td>40 J</td>
<td>40 J</td>
</tr>
<tr>
<td>Sensing to defibrillation period</td>
<td>9.5 s</td>
<td>14.5 s</td>
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<tr>
<td>Shock impedance</td>
<td>74 Ω</td>
<td>53 Ω</td>
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<tr>
<td>Procedure time (“skin to skin”)</td>
<td>82 min</td>
<td>103 min</td>
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<tr>
<td>PRAETORIAN score</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Complications</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

BMI = body mass index; VF = ventricular fibrillation; LVEF = left ventricular ejection fraction.

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**Figure 2** The positional relationship between the incision line, latissimus dorsi muscle (LDM), and intermuscular space. **A:** The cephalic end of the incision line (green arrow) was placed on the anterior border of the LDM (orange dotted line), a finger-breadth distance caudal to the cephalic end line of the subcutaneous implantable cardioverter-defibrillator pocket (blue dotted line). The caudal end was more anterior along the lead run in the inframammary crease, and the incision was slightly curved for up to 6–7 cm length. **B, C:** The anterior border of the LDM was located in at the same position as the marked line, and it could be distinguished from the serratus anterior muscle (SAM), which medially had different muscle fibers.
Acknowledgments

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References