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 inci-

sion 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). Then, a probe was placed in the coronal plane posterior to the midaxillary line to delineate the LDM and SAM and was moved 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 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 (Figure 2A), which corresponded to the short-side length of the S-ICD generator (69.1 × 83.2 × 12.7 mm).

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[3] 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.[4,6,7] 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 anticoagulation and antiplatelet is associated with an increased risk of hematoma.[8–10] 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 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[11] 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
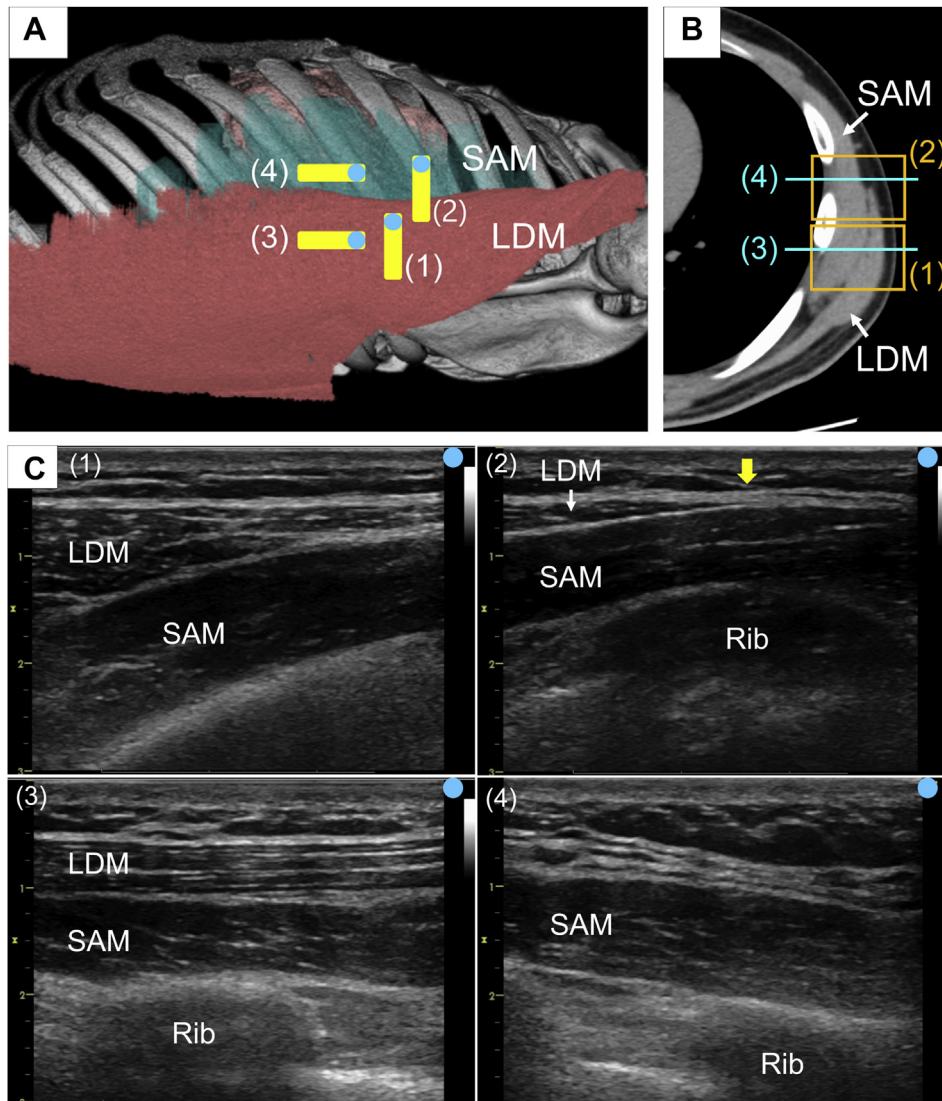
Figure 1   The computed tomography (CT) image and ultrasound image in the second case. A volume-rendered image reconstructed from CT (**A**) and an axial CT image (**B**) in the second case are presented. The serratus anterior muscle (SAM) is highlighted by blue and latissimus dorsi muscle (LDM) by red. The probe markers (*yellow bold line* and *blue circle*) indicate ultrasound probe position of (1), (2), (3), and (4). The probe position of (1) and (2) is placed in the axial plane and that of (3) and (4) in the coronal plane to detect the anterior border of the LDM. The numbers in panels A and B indicating the probe positions represent the same positions in each image. Each ultrasound image obtained at each probe position ((1)-(4)) is presented in panel C (1-4). **C:** The ultrasound images of the LDM and SAM. Each image corresponds to the scan area shown in panels A and B. The anterior border of the LDM is delineated by the yellow arrow in panel C(2). CT = computed tomography; LDM = latissimus dorsi muscle; SAM = serratus anterior muscle.

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[12] 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
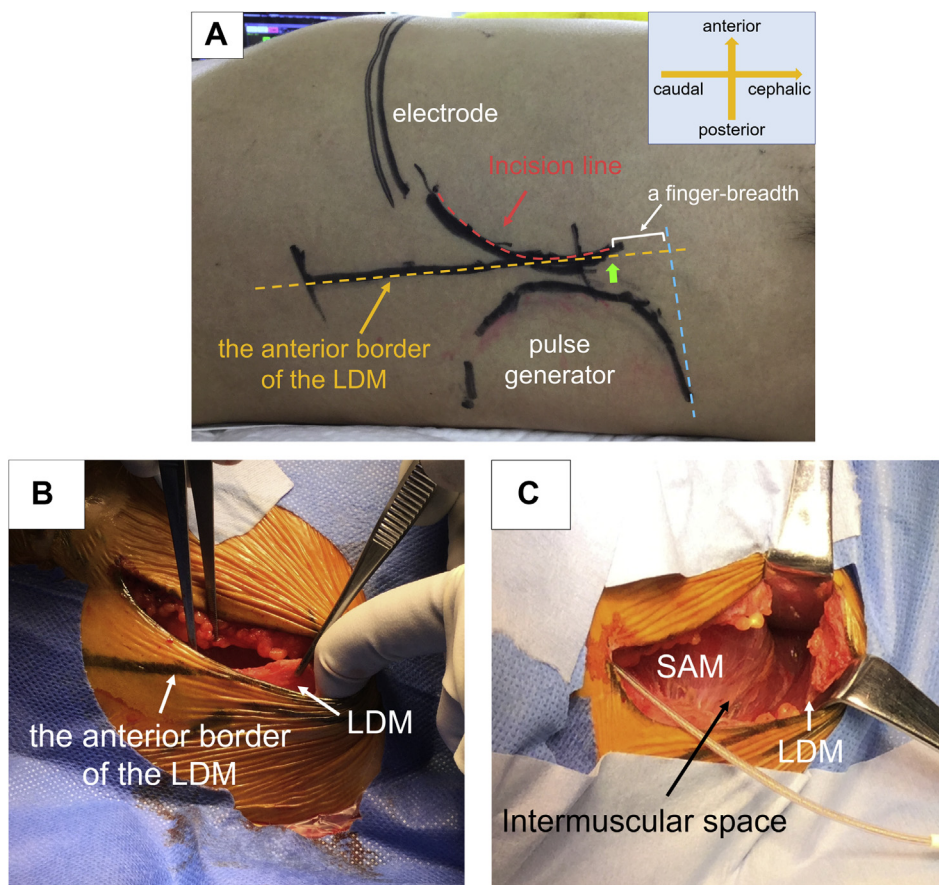
Figure 2   The positional relationship between the incision line, latissimus dorsi muscle (LDM), and intermuscular space. **A:** The cephalic end of the incision line (*green arrow*) was placed on the anterior border of the LDM (*orange dotted line*), a finger-breadth distance caudal to the cephalic 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.

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   Patients' background and outcomes

	Case 1	Case 2
Sex	Male	Male
Age	53	27
BMI (kg/m^2)	28.4	23.7
Indication	Secondary prevention	Secondary prevention
Primary cardiac disease	Idiopathic VF	Brugada syndrome
LVEF	53%	61%
Defibrillation testing		
Shock energy	40 J	40 J
Sensing to defibrillation period	9.5 s	14.5 s
Shock impedance	74 Ω	53 Ω
Procedure time ("skin to skin")	82 min	103 min
PRAETORIAN score	30	30
Complications	None	None

BMI = body mass index; VF = ventricular fibrillation; LVEF = left ventricular ejection fraction.
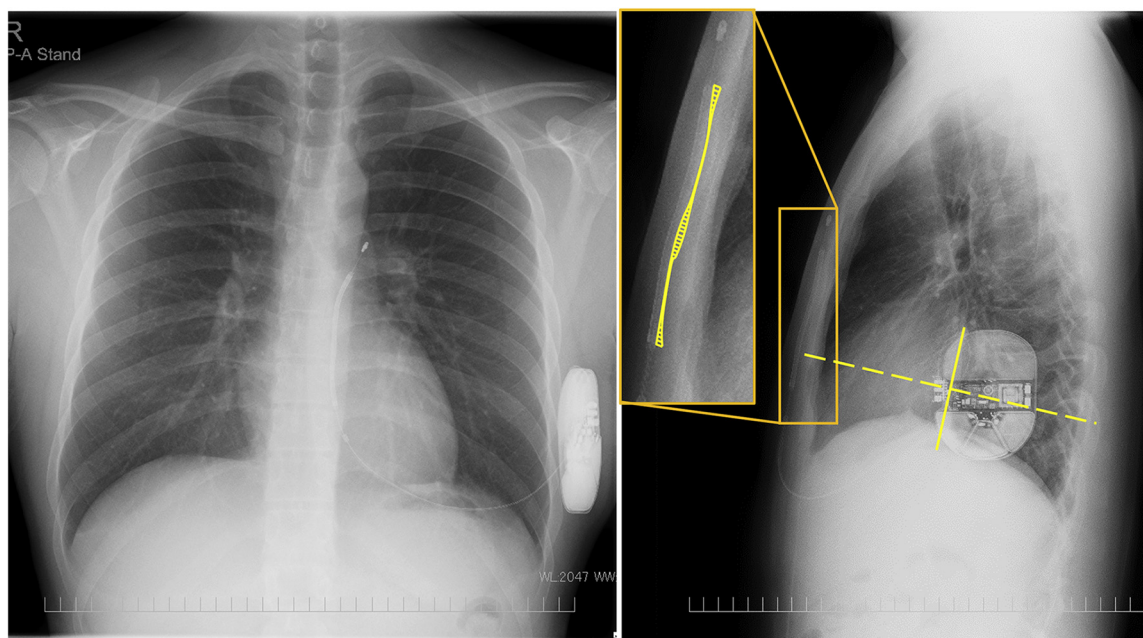
Figure 3   Postimplantation posterior-anterior and lateral chest radiographs. The postimplantation posterior-anterior and lateral chest radiographs were analyzed, and the PRAETORIAN score was 30 (the number of coil widths of fat tissue between the nearest half of the subcutaneous implantable cardioverter-defibrillator coil and sternum or ribs is ≤1, the generator is on the midline, and the amount of fat tissue between the nearest point of the generator and thoracic wall is ≤1 generator width).

Acknowledgments

References

1. Boersma L, Barr C, Knops R, et al. Implant and midterm outcomes of the Subcutaneous Implantable Cardioverter-Defibrillator Registry: the EFFORTLESS study. J Am Coll Cardiol 2017;70:830–841.
2. Heist EK, Belalcazar A, Stahl W, Brouwer TF, Knops RE. Determinants of subcutaneous implantable cardioverter-defibrillator efficacy: a computer modeling study. JACC Clin Electrophysiol 2017;3:405–414.
3. Quast ABE, Baalman SWE, Brouwer TF, et al. A novel tool to evaluate the implant position and predict defibrillation success of the subcutaneous implantable cardioverter-defibrillator: the PRAETORIAN score. Heart Rhythm 2019; 16:403–410.
4. Winter J, Siekiera M, Shin DI, et al. Intermuscular technique for implantation of the subcutaneous implantable cardioverter defibrillator: long-term performance and complications. Europace 2017;19:2036–2041.
5. Migliore F, Allocca G, Calzolari V, et al. Intermuscular two-incision technique for subcutaneous implantable cardioverter defibrillator implantation: results from a multicenter registry. Pacing Clin Electrophysiol 2017;40:278–285.
6. Migliore F, De Franceschi P, De Lazzari M, et al. Ultrasound-guided serratus anterior plane block for subcutaneous implantable cardioverter defibrillator implantation using the intermuscular two-incision technique. J Interv Card Electrophysiol 2020;57:303–309.
7. Letsas KP, Xydonas S, Karamichalakis N, et al. Intermuscular implantation technique for subcutaneous cardioverter-defibrillators. Herz 2019; 44:541–545.
8. Afzal MR, Mehta D, Evenson C, et al. Perioperative management of oral anticoagulation in patients undergoing implantation of subcutaneous implantable cardioverter-defibrillator. Heart Rhythm 2018;15:520–523.
9. Evenson C, Saour B, Afzal MR, et al. Increased risk of hematoma with uninterrupted warfarin in patients undergoing implantation of subcutaneous implantable cardioverter defibrillator. Pacing Clin Electrophysiol 2019; 42:1111–1114.
10. Sheldon SH, Cunnane R, Lavu M, et al. Perioperative hematoma with subcutaneous ICD implantation: impact of anticoagulation and antiplatelet therapies. Pacing Clin Electrophysiol 2018;41:799–806.
11. Biffi M, Bongiorni MG, D'Onofrio A, et al. Is 40 joules enough to successfully defibrillate with subcutaneous implantable cardioverter defibrillators? JACC Clin Electrophysiol 2021;S2405-500X(20). 31121-X.
12. Knops RE, Brouwer TF, Barr CS, et al. The learning curve associated with the introduction of the subcutaneous implantable defibrillator. Europace 2016; 18:1010–1015.