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Noninvasive tissue adhesive for cardiac implantable electronic device pocket closure: the TAPE pilot study

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Abstract

Purpose Device infection is a serious complication of cardiac implantable electronic devices (CIED). Ensuring complete pocket closure can be time consuming, but remains vital to prevent infection. The Zip® Surgical Skin Closure (ZIP) is a noninvasive adhesive device applied to the skin as an alternative to subcuticular sutures for skin closure. We hypothesized that using this device would decrease pocket closure times without increasing the risk of pocket infections. This is a single center, retrospective cohort study to compare pocket closure times and infection rates between ZIP and standard suture for CIED pocket closure.

Methods Two separate groups of consecutive new intravenous implants, upgrades, and pulse generator replacements from October 2015 to April 2017 were included. A total of 175 patients were included, using either ZIP ($n = 80$) or suture ($n = 95$). Total procedure time (local anesthetic to dressing application) and pocket closure time (fascial suture to dressing application) were compared. Pocket infections were defined as infections leading to CIED extraction or wound dehiscence requiring repeat procedure. Statistical analysis was performed using chi square test and Student's t test.

Results Pocket closure time and procedure time were significantly shorter for the ZIP group (14.9 ± 6.8 vs 20.1 ± 11.09 min, $p = 0.0003$) and (65.02 ± 30.4 vs 83.83 ± 40.3 min, $p = 0.0008$), respectively. No pocket infections occurred in the Zip group, while the suture group had 2:1 wound dehiscence and 1 pocket infection.

Conclusion The ZIP device resulted in significantly shorter pocket closure and procedure times without increasing device pocket infections.

Keywords Device pocket closure · Cardiac device implant

Abbreviations

CIED	Cardiac implantable electronic devices
SSI	Superficial surgical site infections
DM	Diabetes mellitus
GFR	Glomerular filtration rate
ICD	Implantable cardioverter defibrillator
PPM	Permanent pacemaker
VSS	Vancouver Scar Scale

1 Background

Cardiac implantable electronic devices (CIED) are a mainstay of therapy in many cardiac patients. As the indications for these devices continue to expand, the number of annual implants has also risen, with over 600,000 annually worldwide [1, 2]. CIED infection is a potentially serious complication of device implantation and can range from superficial surgical site infections (SSI) to deeper, pocket infections that ultimately may lead to system extraction. Achieving appropriate skin approximation and minimal wound tension is important for healing and preventing infections [3, 4].

Standard pocket closure techniques can be a time-consuming process in which final results are operator dependent. An ideal pocket closure technique would minimize interoperator variability, reduce operative time, and still result in appropriate incision closure to prevent infections.

A novel noninvasive tissue adhesion system (Zip® Surgical Skin Closure, ZipLine Medical, Inc., Campbell, CA, USA) was recently developed. This device is applied to the skin as an

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alternative to sutures for the subcuticular layer for closure of surgical incisions. We hypothesized that using the Zip® Surgical Skin Closure system (ZIP) would decrease pocket closure times without negatively affecting infection rates.

2 Methods

This is a single center, retrospective cohort study of 175 patients comparing the efficacy of the ZIP device to the use of standard sutures for CIED pocket closure at the University of Missouri. The study protocol was approved by the institutional review board. No funding source was utilized for the study. All procedures were performed by three attending cardiac electrophysiologists with significant experience in both closure techniques. Consecutive new transvenous implants, upgrades, and pulse generator replacements performed from October 2015 to February 2016 were included in the suture group, and procedures from March 2016 to April 2017 were included in the ZIP group. Prior to March 2016, all procedures were performed with standard sutures, as the ZIP was not available at the study center.

2.1 Procedure

Patients underwent one of three procedures requiring pocket closure: new device implant, device upgrade, or pulse generator replacement. All patients received standard preoperative intravenous antibiotics started within 30 min prior to skin incision. The use of an antibiotic envelope and postoperative antibiotics was performed at operator discretion. The fascia and subcutaneous layers were closed with either 2–0 or 3–0 Vicryl sutures in all patients. In the suture group, the skin layer was closed with running subcuticular sutures using 4–0 Vicryl, followed by application of 2-octyl-cyanoacrylate solution. In the ZIP group, the skin layer was closed using the ZIP system (Zip® Surgical Skin Closure, ZipLine Medical, Inc., Campbell, CA, USA) in place of subcuticular sutures and 2-octyl-cyanoacrylate solution. The ZIP is an adjustable, hydrocolloid adhesive-based system designed for approximation of the superficial skin. The adjustable device is applied by placing the strips of adhesive tape on each side of the incision, and tightening the adjustable plastic ratcheting pieces to close the superficial skin (Fig. 1). The ZIP device remained in place until the first follow-up appointment, 7–14 days following the implant. Patients in both groups were instructed regarding standard post-procedural instructions.

2.2 Outcomes

The primary outcomes of this study were total procedure and pocket closure time. Total procedure time was defined as time from administering local anesthetic to the chest to dressing application. Pocket closure time was defined as the time from the start of the first fascial suture application to dressing application.

The secondary outcome was infection rate. Two main categories of infections were documented: surgical site infections (SSI) and pocket infections. SSI infections were defined as any superficial erythema or discharge localized to the incision site requiring oral antibiotics. Pocket infections were defined as deeper infections involving the device pocket or any part of the device system requiring intravenous antibiotics or need for repeat procedure such as explant or repeat closure for wound dehiscence.

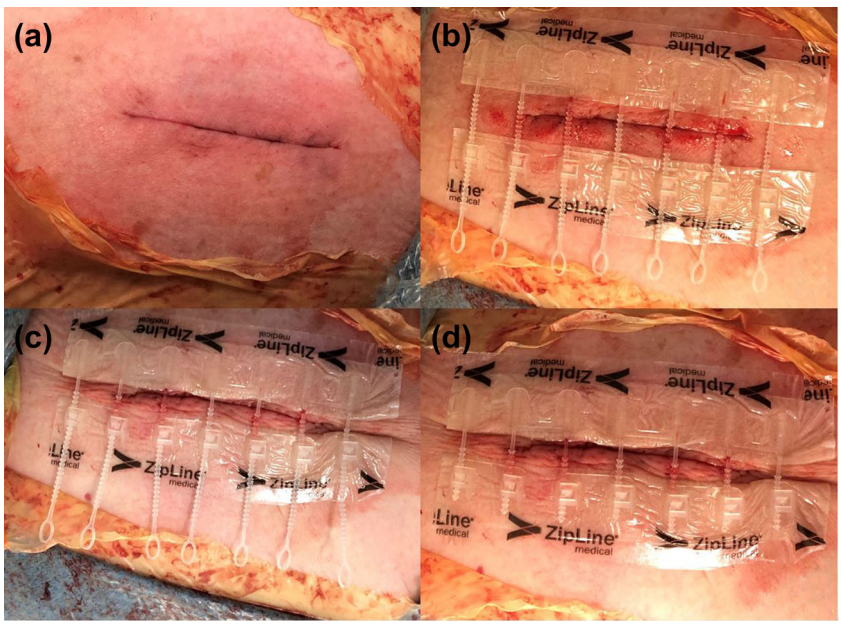

Fig. 1 ZIP device application for PPM implant. **a** Pocket appearance after suture closure of fascial and subcutaneous layers. **b** Initial application of ZIP device. **c** ZIP device after tightening plastic ratcheting system. **d** Final appearance of ZIP device pocket closure

Risk factors previously shown to increase risk of infection were documented. These include diabetes mellitus (DM), chronic kidney disease (GFR < 60 ml/min), current anticoagulation, steroid use, > 2 leads, fever/leukocytosis at time of procedure, generator change/upgrade, pacemaker dependence, prior CIED infection, and early pocket reopening within 2 weeks of initial procedure [5–8].

2.3 Statistical analysis

Continuous variables are presented as mean and standard deviation if parametric, and median and interquartile range for non-parametric data. Categorical variables are presented as frequency and percentages. Statistical analysis was performed using chi square test and Fisher's exact test for categorical variables. Continuous variables were compared using Student's *t* test, linear regression analysis, and analysis of variance (ANOVA). A p value < 0.05 was considered statistically significant. STATA 13 statistical software (Statacorp, College Station, TX, USA) was utilized for analysis.

3 Results

A total of 175 patients were included in this study, 95 treated with suture closure, and 80 treated with ZIP. Patient characteristics and device type for each group are summarized in Table 1. Both groups were similar in CIED infection risk factors and use of an antibiotic envelope. There were a higher number of dual chamber devices in the ZIP group [50 (62.5%) vs 45 (47.4%), $p = 0.049$]. The number of implantable cardioverter defibrillators (ICDs) was significantly higher in the suture group [26 (32.5%) vs 62 (65.3%), $p < 0.001$].

The results of the primary endpoints are summarized in Table 2. Pocket closure time was significantly shorter in the ZIP group (14.9 ± 6.8 vs 20.1 ± 11.1 min, $p = 0.0003$). Total procedure time was also significantly shorter in the ZIP group (65 ± 30.4 vs 83.8 ± 40.3 min, $p = 0.0008$). Use of the antibiotic envelope may increase pocket closure time, but this was similar between groups. Given the imbalance between ICD and PPM between groups, further analyses on pocket closure time were performed. For ICDs, pocket closure time was significantly shorter in the ZIP group (16.1 ± 7.5 vs 21.7 ±

Table 1 Baseline patient and procedural characteristics

	Zip ($n = 80$)	Suture ($n = 95$)	p value
Average age, years	70.7 ± 12.7	65 ± 13.4	< 0.01
Male gender, *n* (%)	43 (53.8)	42 (44)	0.23
CIED infection risk factors, *n* (%)			
Diabetes mellitus	25 (31.3)	31 (32.6)	0.87
Chronic kidney disease	25 (31.3)	37 (38.9)	0.34
Oral anticoagulation	27 (33.3)	20 (21)	0.06
Steroid use	1(1.3)	4 (4.2)	0.38
Early pocket reentry	0	1 (1)	1
> 2 leads	15 (18.8)	31 (32.6)	0.04
Prior CIED infection	0	0	1
Fever/leukocytosis	4 (5)	11 (11.6)	0.18
PPM dependent	31 (38.8)	42 (44.2)	0.54
Average CIED infection risk factors	2.0	2.2	0.23
Antibiotic envelope use, *n* (%)	27 (33.8)	40 (42.1)	0.28
Device type, *n* (%)			
Total ICDs	26 (32.5%)	62 (65.3%)	< 0.001
Bi-V ICD	14 (17.5)	27 (28.4)	0.11
Bi-V PPM	3 (3.8)	3 (3.2)	1.0
Dual chamber devices	50(62.5)	45(47.4)	0.049
Dual chamber ICD	9 (11.3)	16 (16.8)	0.39
Dual chamber PPM	41 (51.3)	29 (30.5)	0.008
Single chamber devices	13 (16.3)	20(21.1)	0.44
Single chamber ICD	3 (3.8)	19 (20)	0.001
Single chamber PPM	10 (12.5)	1 (1.1)	0.003
New implants	51 (63.8)	58 (61.1)	0.76
Upgrade/generator change	29 (36.3)	37 (38.9)	0.76

Table 2 Procedural time results

	Zip ($n = 80$)	Suture ($n = 95$)	p value
Total procedure time ± SD, min	65 ± 30.4	83.8 ± 40.3	0.0008
Pocket closure time ± SD, min	14.9 ± 6.8	20.1 ± 11.1	0.0003
ICD pocket closure time ± SD, min	16.1 ± 7.5	21.7 ± 12.1	0.037
PPM pocket closure time ± SD, min	14.2 ± 6.3	17.3 ± 7.9	0.051

12.1 min, $p = 0.037$). Similarly, there was also a trend towards shorter pocket closure times for pacemakers with the ZIP group (14.2 ± 6.3 vs 17.3 ± 7.9 min, $p = 0.051$), although not statistically significant.

Differences in pocket closure times for ICDs and PPM were compared for each treatment group. In the suture group, ICD pocket closure time was significantly longer than PPM pocket closure time (21.68 ± 12.1 vs 17.27 ± 7.9 min, $p = 0.038$). No significant difference was observed between ICD and PPM pocket closure time in the ZIP group (16.11 ± 7.5 vs 14.18 ± 6.3 min, $p = 0.24$). Interoperator variability was statistically similar between the suture and ZIP groups ($p = 0.056$).

Infection results are summarized in Table 3. Total infections (SSI + pocket) were numerically lower in the ZIP group, but this was not significant [2 (2.5%) vs 5 (5.6%), $p = 0.46$]. No pocket infections occurred in the ZIP group and two pocket infections occurred in the suture group [0 vs 2 (2.1%), $p = 0.50$]. The pocket infections in the suture group included one patient requiring system extraction due to a staphylococcal infection. The second patient had a wound dehiscence requiring repeat procedure. Average time from implant to infection was 13 days in the ZIP group and 28.6 days in the suture group. Average follow-up was significantly longer in the suture group (221.9 days vs 73.8 days, $p < 0.00001$), but all infections in the study occurred within 34 days. No other complications were observed relating to pocket closure in either group.

4 Discussion

The main findings of this study are a significant decrease in pocket closure time and procedure time with use of the ZIP system. Pocket closure time was an average of 5.2 min shorter with the ZIP system compared to standard sutures. The mean difference in pocket closure time was 5.6 min for ICDs and only 3.1 min for PPMs, suggesting that the ZIP device is most beneficial with longer incisions. Furthermore, pocket closure time for ICDs was significant longer compared to PPMs in the suture group. In the ZIP group, there was no statistical difference in pocket closure time between ICDs and PPMs, suggesting no significant increase in ZIP application time with longer incisions.

Table 3 Infection results

	Zip ($n = 80$)	Suture ($n = 95$)	p value
Total infections, n (%)	2 (2.5)	5 (5.6)	0.46
SSI	2	3	1
Pocket	0	2	0.50
Number of extractions	0	1	1
Wound dehiscence	0	1	1
Average time to infection, days	13	28.6	
Range time to infection, days	5–21	24–34	
Average follow-up, days	73.8 ± 54.8	221.3 ± 122.7	< 0.01

Current standards of pocket closure vary between institutions, but typically involve closure of three layers (fascia, subcutaneous, and subcuticular/intradermal) followed by application of a skin barrier such as 2-octyl-cyanoacrylate solution. Adhesive-based closure devices have been shown to have shorter procedure times compared to sutures [9, 10]. In a series of 40 patients, Lalani et al. found the ZIP device had a shorter overall closure time (78 ± 6.6 s vs 216 s, $p < 0.001$) as well as a shorter mean closure time per centimeter compared to standard sutures (18.0 ± 2.0 s/cm vs 50.1 ± 6.7 s/cm, $p < 0.001$) [9]. Additionally, they reported significantly lower interoperator variability with the ZIP device compared to sutures. In our study, both groups displayed significant interoperator variability for pocket closure time, but this is likely due to our definition of pocket closure. Our definition of pocket closure included all layers, rather than only skin closure time, which Lalani et al. used in their study. Furthermore, the ZIP device has also been shown to decrease skin closure time in other surgical procedures including orthopedic and cardiothoracic surgical procedures [10]. The present study is the largest to date examining the efficacy of the ZIP device in CIED pocket closures.

Surgical site infections and pocket infections were higher in the suture group, but this did not reach statistical significance, in part, due to small sample size. No previous studies have examined the rates of CIED infections between the ZIP device and standard sutures. The device has been shown to have similar infection rates in other types of procedures [10]. Proper incision closure is vital for optimal wound healing as insufficient wound closure and delayed wound closure are known risk factors for subsequent infections [11]. Commonly used options for skin closure include subcuticular (or intradermal) absorbable suture, adhesive-based products, and staples [12]. Standard sutures and staples hold incisions together at single points in which the material passes through the incision, which

creates focal points of increased wound tension. The ZIP device equally distributes pressure across the wound to minimize wound tension and ensure complete coaptation. Staples, and potentially sutures, puncture the dermis leaving tracts for potential infections. Adhesive-based skin closure leaves dermal layers intact and has been found to decrease SSIs compared to staples or standard sutures [13, 14].

Scar formation and cosmetic appearance are common complaints after surgical procedures. Tanaka et al. examined used the Vancouver Scar Scale (VSS) to objectively compare scar appearance between the ZIP device and sutures in 214 sternotomy patients. The VSS, first described in 1990, is the most frequently used scoring system to evaluate the cosmetic appearance of surgical scars, with lower values representing more normal skin [15–18]. Among patients undergoing a first operation, Tanaka et al. reported a significantly lower VSS score in each of the four categories in the ZIP compared to sutures [10]. In another study, Lalani et al. used patient surveys to assess cosmetic appearance of scar following CIED procedures with the ZIP device. They reported no statistical difference in subjective scar appearance between the device and standard sutures [9].

The cost of the ZIP device has been reported to range from $60–85 [9, 10]. Although this is higher than the cost of sutures, there may be potential cost saving with the ZIP system [9]. In addition to replacing the subcuticular suture, the ZIP system also replaces the 2-octyl-cyanoacrylate solution, which decreases the cost difference. The cost of 2-octyl-cyanoacrylate solution ranges from $20–27.27 per vial [[19] with an additional $5–6 for a Vicryl suture. A cost effectiveness analysis should be performed to assess whether the time saved during pocket closure translates into higher procedure volumes.

4.1 Study limitations

The results of this study should be interpreted in light of several methodological limitations. First, this is a retrospective cohort study. Additionally, although this is the largest known study comparing the ZIP device with sutures in CIED procedures, the study was underpowered for a CIED infection analysis. Follow-up was also significantly different between the groups. Furthermore, subcutaneous ICDs were excluded from the study due to low implant volume at the time of the study.

5 Conclusion

In this proof of concept pilot study, the ZIP noninvasive surgical skin closure device significantly shortened pocket closure and procedure times compared to standard sutures without increasing the rate of CIED infections.

Authors' contributions Scott Koerber: concept/design, data collection, data analysis/interpretation, drafting article, critical revision of article, statistics, approval of article.

Troy Loethen: data collection, data analysis/interpretation, critical revision of article, approval of article.

Mohit K. Turagam: data analysis/interpretation, critical revision of article, approval of article.

Josh Payne: data collection, approval of article.

Richard Weachter: critical revision of article, approval of article.

Greg Flaker: critical revision of article, approval of article.

Michael R. Gold: data analysis/interpretation, critical revision of article, approval of article.

Sandeep Gautam: concept/design, data analysis/interpretation, critical revision of article, statistics, approval of article.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This study protocol was approved by the institutional review board.

Disclosures None for any author relative to this article.

References

1. Christopher Ellis MD, Kolek M. Rising infection rate in cardiac electronic device implantation; the role of the AIGISRx ® antibacterial envelope in prophylaxis. Comb Prod Ther. 2011:I.
2. Greenspon A, Patel J, Lau E, Ochoa J, Frisch D, Ho R, et al. 16-year trends in the infection burden for pacemakers and implantable cardioverter-defibrillators in the United States. J Am Coll Cardiol. 2011;58(10):1001–6.
3. Imai K. Perioperative management for the prevention of bacterial infection in cardiac implantable electronic device placement. J Arrhythmia. 2016;32(4):293–86.
4. Altemeier WA. Manual on control of infection in surgical patients: Lippincott; 1984.
5. Klug D, Balde M, Pavin D, Hidden-Lucet F, Clementy J, Sadoul N, et al. Risk factors related to infections of implanted pacemakers and cardioverter-defibrillators: results of a large prospective study. Circulation. 2007;116(12):1349–55. https://doi.org/10.1161/circulationaha.106.678664.
6. Lekkerkerker JC, van Nieuwkoop C, Trines SA, van der Bom JG, Bernards A, van de Velde ET et al. Risk factors and time delay associated with cardiac device infections: Leiden device registry. Heart (British Cardiac Society). 2009;95(9):715–720. doi:https://doi.org/10.1136/hrt.2008.151985.
7. Sohail MR, Uslan DZ, Khan AH, Friedman PA, Hayes DL, Wilson WR, et al. Management and outcome of permanent pacemaker and implantable cardioverter-defibrillator infections. J Am Coll Cardiol. 2007;49(18):1851–9. https://doi.org/10.1016/j.jacc.2007.01.072.
8. Bloom H, Heeke B, Leon A, Mera F, Delurgio D, Beshai J, et al. Renal insufficiency and the risk of infection from pacemaker or defibrillator surgery. Pacing Clin Electrophysiol. 2006;29(2):142–5. https://doi.org/10.1111/j.1540-8159.2006.00307.x.
9. Lalani GG, Schricker AA, Salcedo J, Hebsur S, Hsu J, Feld G, et al. Cardiac device implant skin closure with a novel adjustable, coaptive tape-based device. Pacing Clin Electrophysiol. 2016;39(10):1077–82. https://doi.org/10.1111/pace.12926.

10. Tanaka Y, Miyamoto T, Naito Y, Yoshitake S, Sasahara A, Miyaji K. Randomized study of a new noninvasive skin closure device for use after congenital heart operations. Ann Thorac Surg. 2016;102(4):1368–74. https://doi.org/10.1016/j.athoracsur.2016.03.072.
11. De Maria E, Diemberger I, Vassallo PL, Pastore M, Giannotti F, Ronconi C, et al. Prevention of infections in cardiovascular implantable electronic devices beyond the antibiotic agent. J Cardiovasc Med (Hagerstown). 2014;15(7):554–64. https://doi.org/10.2459/jcm.0000000000000008.
12. Moy RL, Lee A, Zalka A. Commonly used suturing techniques in skin surgery. Am Fam Physician. 1991;44(5):1625–34.
13. Iavazzo C, Gkegkes ID, Vouloumanou EK, Mamais I, Peppas G, Falagas ME. Sutures versus staples for the management of surgical wounds: a meta-analysis of randomized controlled trials. Am Surg. 2011;77(9):1206–21.
14. Spencker S, Coban N, Koch L, Schirdewan A, Mueller D. Comparison of skin adhesive and absorbable intracutaneous suture for the implantation of cardiac rhythm devices. Europace. 2011;13(3):416–20. https://doi.org/10.1093/europace/euq394.
15. Fearmonti R, Bond J, Erdmann D, Levinson H. A review of scar scales and scar measuring devices. Eplasty. 2010;10:e43.
16. Bae SH, Bae YC. Analysis of frequency of use of different scar assessment scales based on the scar condition and treatment method. Arch Plast Surg. 2014;41(2):111–5. https://doi.org/10.5999/aps.2014.41.2.111.
17. Lee SH, Zheng Z, Roh MR. Early postoperative treatment of surgical scars using a fractional carbon dioxide laser: a split-scar, evaluator-blinded study. Dermatologic surg. 2013;39(8):1190–6. https://doi.org/10.1111/dsu.12228.
18. Truong PT, Abnousi F, Yong CM, Hayashi A, Runkel JA, Phillips T, et al. Standardized assessment of breast cancer surgical scars integrating the Vancouver Scar Scale, Short-Form McGill Pain Questionnaire, and patients' perspectives. Plast Reconstr Surg. 2005;116(5):1291–9.
19. Glennie RA, Korczak A, Naudie DD, Bryant DM, Howard JL. MONOCRYL and DERMABOND vs staples in total hip arthroplasty performed through a lateral skin incision: a randomized controlled trial using a patient-centered assessment tool. J Arthroplast. 2017;32(8):2431–5. https://doi.org/10.1016/j.arth.2017.02.042.