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Short communication

Forces on sutures when closing excisional wounds using the rule of halves

William Lear[a], Lacey L. Roybal[a], Jamie J. Kruzic[b,*]

[a] Departments of Dermatology and Dermatologic Surgery, Silver Falls Dermatology, Corvallis, OR, 97330, USA
[b] School of Mechanical and Manufacturing Engineering, UNSW Sydney, Sydney, NSW 2052, Australia

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ABSTRACT

Background: To close elliptical excisions, surgeons commonly use the rule of halves which involves initially closing of the middle portion of the wound, followed by closure of the remaining halves. Understanding the forces required for suturing such wounds can aid excisional surgery planning to decrease complications and improve wound healing.

Methods: Following full thickness excision for removal of skin cancers, back wounds with 3:1 ratio of length-to-width were closed using the rule of halves. The force required to bring the wound edges into contact at the middle portion of the wound was measured, followed by the two bisected halves.

Findings: The average force to close the center of the wounds averaged 3.7 N and was six times larger than that of the bisected halves. The forces to close the bisected halves were consistently small, and essentially negligible (< 0.5 N) for ~50% of the cases.

Interpretation: When planning excisional surgery to avoid complications such as tearing the dermis (cheese wiring), the use of special wound closure techniques (high tension and/or pully sutures, skin support or suture retention devices, etc.) should focus on the center suture only when using the rule of halves, as the remaining sutures require very low forces.

1. Introduction

Elliptical or fusiform excisions are the most common form of excision performed for skin lesion removal (Oh and Lee, 2013). The advantages include simplicity, minimization of tissue removal, minimization of scar lines, and acceptable cosmetic outcomes (Goldberg and Alam, 2004). Traditionally, an elliptical excision is designed with a 3:1 length-to-width ratio to minimize "dog ear" formation (Goldberg and Alam, 2004; Oh and Lee, 2013). To close elliptical excisions, surgeons commonly use the rule of halves (Fig. 1a). This involves initial closure of the middle portion of the wound, followed by closure of the remaining halves.

Understanding the forces required for suturing such wounds can aid excisional surgery planning to decrease complications (e.g., cheese wiring, where the sutures cut through the skin) and improve wound healing. In the latter case, mechanical forces are well known to affect wound healing (Agha et al., 2011; Harn et al., 2019; Levi et al., 2016). Although previous studies have analyzed the forces required for closing elliptical wounds (Cacou et al., 1994; Capek et al., 2012), information is lacking for sutures placed at specific locations across the wound. The aim of this study was to analyze the wound closure forces across the center and two bisected halves of elliptical skin lesions closed according to the rule of halves. It is anticipated that understanding the magnitude of these forces will provide practical guidance for planning and anticipating complications in elliptical excisional surgery.

2. Methods

A prospective, single-center, IRB-approved (SHS IRB18-083) trial was performed with 18 patients ($N = 11$ male aged 56–86, $N = 7$ female aged 46–91) who presented for removal of skin cancers from the back. All excisions were marked with a 3:1 ratio of length-to-width. After local anesthesia with 0.5% lidocaine with 1:1,000,000 epinephrine, full thickness excision was performed in each case followed by electrosurgery for hemostasis. Wound dimensions were measured to ± 0.5 mm accuracy using a calibrated ruler. The middle portion of the wound was initially closed using a large bite percutaneous 2–0 nylon suture. A calibrated force gauge (Series 3 Digital Force Gauge; Mark-10 Corporation; Copiague, NY, USA) was welded to a mosquito clamp that allowed for easy securing of the suture (Fig. 1b). The clamp was maintained in parallel alignment with the suture and both were oriented perpendicular to the wound. In this manner, the force required to bring the wound edges into contact was measured with ± 0.02 N accuracy (Fig. 1b). After measuring the tension force, the nylon suture

* Corresponding author.
E-mail address: j.kruzic@unsw.edu.au (J.J. Kruzic).

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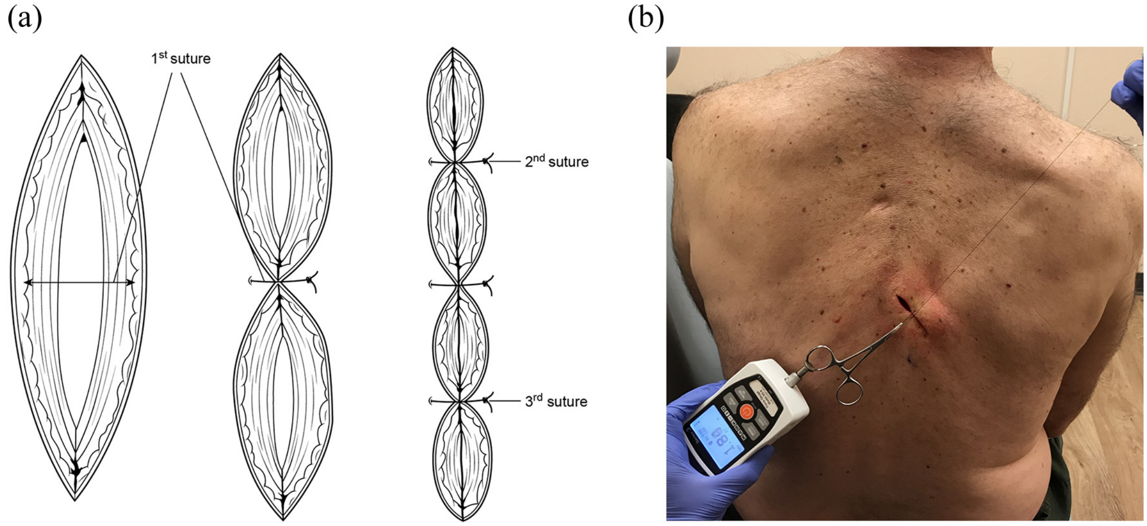

Fig. 1. (a) Schematic of the rule of halves used for closing elliptical wounds. (b) Photo showing how force measurement was conducted.

was removed and replaced with a 3–0 Polysorb buried suture. The two bisected halves of the wound were closed in the same manner, with an identical force measurement procedure.

3. Results

Wound dimensions and closure forces are shown in Table 1. Force data was not normally distributed as determined by the Shapiro-Wilk test; accordingly, the Kruskal-Wallis test was applied with $p < .05$ considered statistically significant. There was no statistically significant effect of gender, so all data were grouped together. The average force to close the center of the wounds was six times larger than that of the bisected halves, and this difference was statistically significant ($p < .001$). There was no statistically significant difference between the force required to close the bisected halves.

4. Discussion

The average maximal force for the first suture found in this study was 3.7 N, which is similar to the value of 3.2 N found by Capek et al. for elliptical back wounds with similar aspect ratio (~2) to this study (Capek et al., 2012). The somewhat smaller value found by Capek et al. is likely reflective of the smaller average wound length used in that study (~4.6 cm vs. 6.6 cm) and also only two experiments were conducted with an aspect ratio near 2. Another previous study examined limb wounds and the results are not readily comparable to the present work (Cacou et al., 1994).

While it is not surprising that the force is lower for the bisected halves, the magnitude of the difference is of practical interest. The forces to close the bisected halves were consistently small (Table 1), and essentially negligible (< 0.5 N) for ~50% of the cases. Data from this study highlight that wound closure using the rule of halves can be partitioned into two distinct phases: i) initial approximation of the wound requiring high tension force and ii) subsequent addition of supports (e.g. sutures, staples, adhesives, or tapes) to maintain closure and facilitate healing. For patients and body sites with very thin skin, the tension required to achieve initial wound edge approximation can exceed the strength of the skin. The results of this study suggest that the

Table 1
Wound dimension and closure force data. Also shown are the age and gender of each patient.

Gender	Age (years)	Width (cm)	Length (cm)	Aspect Ratio	Force Center Suture (N)	Force Second Suture (N)	Force Third Suture (N)
F	78	4.8	9.0	1.88	2.38	0.64	0.48
M	79	2.8	6.2	2.21	2.06	1.38	0.38
M	77	1.9	4.9	2.58	2.18	0.28	0.20
F	65	2.4	5.2	2.17	3.72	0.68	0.10
F	62	1.8	4.5	2.50	0.98	0.10	0.14
F	91	3.6	8.5	2.36	0.96	0.24	0.34
F	70	2.2	4.8	2.18	2.40	0.22	0.68
M	86	4.0	7.2	1.80	5.68	2.08	0.66
M	64	2.2	4.5	2.05	2.36	0.16	0.26
F	46	2.4	4.5	1.88	4.36	1.24	1.00
M	72	5.0	13.2	2.64	3.74	1.28	1.78
M	71	2.8	6.0	2.14	9.45	0.58	0.56
F	59	2.6	5.9	2.27	7.50	1.46	0.20
M	56	2.1	5.5	2.62	3.24	0.30	0.30
M	67	2.4	6.2	2.58	3.38	0.16	0.80
M	72	2.9	6.0	2.07	3.64	0.82	0.30
M	72	1.9	6.2	3.26	1.44	0.10	0.20
M	56	6.2	11.0	1.77	6.38	0.68	1.02
Average	69	3.0	6.6	2.28	3.66	0.69	0.52
Standard deviation	11	1.2	2.4	0.38	2.30	0.58	0.42

risk of tearing the dermis (cheese wiring) is only associated with the initial suture when using the rule of halves. This provides guidance for anticipating and avoiding complications during relatively challenging excisional surgeries.

For example, wounds requiring very high closure forces, such as in the scalp (Lear et al., 2019), invariably provide a surgical challenge. In addition to the afore mentioned risk of cheese wiring, complications from high tension force during wound closure also include dehiscence, scar widening, and scar depression (Oh and Lee, 2013). To avoid such complications, novel techniques have been developed to achieve initial wound approximation. High tension and pulley sutures are often utilized, but these sutures may be traumatic to the skin, causing tissue damage and increased risk of tissue necrosis (Malone et al., 2017). To avoid such damage, some techniques focus on reinforcing the skin itself (Foster and Chan, 2011), while others utilize devices (e.g. SUTUREGARD device) to help better distribute the pressure of the suture (Blattner et al., 2018; Stoecker et al., 2019). The results of the present study suggest that when using the rule of halves, the usage of special techniques, and any associated damage (e.g., from high tension and pully sutures), can be limited to the center suture since the subsequent sutures experience very small forces.

For deep wounds requiring high tension forces to approximate, a bilayered closure is standard with the placement of buried dermal sutures and superficial non-absorbable sutures. Deep absorbable sutures have been found to decrease tension, approximate wound edges, and minimize dead space during healing (Kudur et al., 2009). Various techniques are utilized but commonly the deep sutures are placed across the center of the wound to support the middle portion with the highest tension. While this strategy is consistent with the results of the present study, recent studies have demonstrated that the use of buried dermal sutures do not necessarily provide increased wound strength (Townsend et al., 2016). Thus, while the present findings demonstrate that the initial closure of the high-tension mid-portion of wounds is most important to decreasing complications, there are various types of challenging wounds and corresponding strategies to address them, highlighting the need to further research into the optimal methods of wound closure.

There are several limitations to this study. First, only back wounds were examined while the general biomechanical response of skin can be considered as inhomogeneous, anisotropic, and site specific. Accordingly, the wound closure behavior found in this study might not be consistent for all skin locations. For example, scalp skin may behave quite differently due to its a strong and tough underlying layer of galea aponeurotica (Raposio and Nordström, 1998).

Finally, the age range of this study was limited to those ages typical of skin cancer patients. Thus, the results cannot necessarily be generalized to include younger skin, which in some studies has shown different mechanical properties (Agache et al., 1980; Escoffier et al., 1989; Krueger et al., 2011). For the age range studied, no correlation was found between age and maximum closure force. This is because skin laxity is controlled much more by body location (in this case testing was always on the back) and the specific patient than age. It is clinically observed that elderly patients, in the same location, can have skin ranging from very loose to very tight. The range of force data for the various patients is considered consistent with the biological patient variation that is seen clinically.

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Declaration of competing interest

The authors declare that there are no conflicts of interest.

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