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How Secure are Surgical Knots in Practice-Implications for Surgical Oncological Therapy?

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Abstract

Objective: Secure knots are essential in all areas of surgical practice, particularly in oncological surgery. Our hypothesis was that technique of formation of each layer of a surgical knot was important to its security.

Design: Equal numbers of knots were tied, by each of three groups, using three techniques, for each of four suture materials; a standard Flat Reef Knot (FRK), Knots Tied under Tension(TK), mimicking securing knots at depth within a body cavity, and knots laid without appropriate hand crossing (NHCK). Each knot technique was performed reproducibly, and tested by distraction with increasing force, till each material broke, or the knot separated completely.

Setting: Temporary knot tying laboratory.

Materials: The suture materials were, 2/0 polyglactin 910 (vicryl), 3/0 polydioxanone (PDS), 4/0 poliglecaprone 25 (monocryl) and 1 nylon (Ethilon).

Participants: The three groups comprised a senior surgeon, a resident surgeon, and three medical students.

Outcome measures: Proportion of each knot type that slipped, degree of slippage, and length of suture held in loop secured by each knot type.

Results: 20% of Flat Reef Knots (FRK) tied with all suture materials slipped; all knots tied with the other two techniques, with all materials, slipped, TK (100%) and NHCK (100%). The quantitative degree of slip was significantly less for FRK (mean 6.3% 95%CI 2.2%-10.4%) than for TK (mean 312% 95%CI 280.0%-344.0%) and NHCK (mean 113.0% 95%CI 94.3%-131.0%).

The mean length of suture in loops held within flat reef knots, (FRK mean 25.1 mm 95% CI 24.2 mm-26.0 mm) was significantly greater than mean lengths held by the other techniques (TK mean 17.0 mm 95%CI 16.3 mm-17.7 mm), (NHCK mean 16.3 mm 95%CI 15.9 mm-16.7 mm). The latter two types of knot may have tightened more than anticipated, in comparison to flat reef knots, with potential undue tissue tension.

Conclusion: Meticulous technique of knot tying is essential for secure knots, appropriate tissue tension, and the security of anastomoses and hemostasis effected.

Keywords: Knot security; Suture material; Flat reef knot; Knots tied under tension

Introduction

We recently submitted an article “How to tie dangerous surgical knots-easily. Can we avoid this” [1]. Though the title sounded somewhat dramatic, we believe it reflects an uncomfortable truth.

Inherently, surgeons tend to believe that the knots they form during surgical procedures are secure, and we might assume that this should be relatively simple to achieve. However, access to some body cavities, and location where a suture or ligature is laid, may make it difficult to form a flat reef knot, or other knot, to secure the intended anastomosis or control of a blood vessel.

Our initial study demonstrated that it was disturbingly easy to form an insecure knot with the types of suture material in common use today. All knots formed when our participants failed to cross their hands appropriately, and all knots formed by participants mimicking a situation of tying a knot at depth in a body cavity, holding the suture

material under tension whilst forming each layer,slipped on subsequent testing, and slipped significantly (Table 1).

Our test bed required each participant to tie two metal rings together securely, with each of four suture materials, 2/0 polyglactin 910 (vicryl), 3/0 Polydioxanone(PDS), 4/0 poliglecaprone 25 (monocryl) and 1 nylon (Ethilon), and the security of each knot was tested by distracting the rings apart. Three outcomes were observed; knots could break without any slippage, they could slip to some degree and then break, or they could slip completely without fracture of the suture material. The degree of slippage, if any, was assessed by measuring how much extra suture material would appear within the loop holding the two metal rings. Three knot techniques were used, a flat reef knot technique, and the two techniques above. The mean amount of slippage observed with knots tied when the operator deliberately failed to cross their hands appropriately, was 113% (95% CI 94.3%-131.0%), that observed with knots tied under continual tension was 312% (95% CI 280.0%-344.0%) (Table 1). In contrast, only 20% of knots tied with a flat reef knot technique, forming each layer of the knot with equal amounts of both suture ends, and without undue tension on one end, slipped to any degree, and the mean degree of slip was 6.3% (95%CI 2.2%-10.4%) (Table 1).

Method of formation of square reef knot	Number of knots tied	Number, and proportion(%) of knots that slipped on testing	Mean length of slippage, mm, and proportional degree of slippage, (%), recorded for knot method	95% Lower CI, mm(%)	95% Upper CI, mm(%)	Median length of slippage mm
Flat Reef Knot(FRK)	120	24 (20)	1.2 (6.3)	0.5 (2.2)	2.0 (10.4)	0
No Hand Crossing Knot(NHCK)	120	120 (100)	18.5 (113.0)	15.5 (94.3)	21.5 (131.0)	11.9
Knot tied under tension(TK)	120	120 (100)	50.6 (312.0)	45.9 (280.0)	55.4 (344.0)	51.5

Table 1: Number of knots tied with each method, and proportion of knots tied with each method that slipped on testing, mean length of slippage mm and proportional increase in amount of suture material held within knot post slippage, for each method, and 95% confidence intervals.

The mean lengths of suture material incorporated into knots, that is, the length of material in the loop tied around the hooks, held by the knot, was measured for all 360 knots. The average lengths of suture material included in the loop for knots tied under tension (TK mean 17.0 mm 95%CI 16.3 mm-17.7 mm), and those tied without the operator crossing their hands (NHCK mean 16.3 mm 95% CI 15.9 mm-16.7 mm) were significantly lower than that for flat reef knots (FRK mean 25.1 mm 95%CI 24.2 mm-26.0 mm) (Table 2). This would suggest that that the first two types of knot may tighten more than anticipated, once they are initially formed, in comparison to flat reef knots, and this further tightening may potentially produce undue tissue tension, which may affect tissue viability and healing.

Method of formation of square reef knot	Total number of knots formed	Mean length of suture material incorporated into loop held by knot mm	95% lower CI of mean	95% upper CI of mean
Flat Reef knot(FRK)	120	25.1	24.2	26
No Hand Crossing Knot(NCHK)	120	16.3	15.9	16.7
Knot tied under tension(TK)	120	17	16.3	17.7

Table 2: Mean lengths of suture material incorporated into loop holding hooks in test bed, for each type of knot method.

Technique or Material-Where is the problem?

We would suggest the failures observed with two of the knot tying methods in our initial study were due to the techniques employed. We observed no significant difference in the proportion of knots that slipped between the four materials used in the study, braided and monofilament sutures (Table 3). Once knots did slip, the stronger suture material, 1 nylon, did appear to slip to a greater length than other materials; it was more resistant to subsequent fracture than the others.

A knot relies on adequate friction between the strands of material laid against each other [2], and a reef knot relies on equal amounts of both suture ends placed in each layer of the knot [3]. If formed with an appropriate technique, the flat reef knot technique in this case, adequate friction can be achieved; 80% did not slip, and those that did only slipped to a small degree (Table 1).

Video recording of formation of these knots revealed that in some, twists of the suture material developed just as some layers were laid down, producing unequal amounts of suture in each layer. This would reduce friction, and may account for some of these knots slipping on testing.

The technique of knot formation, rather than suture material, has been considered to be important in knot security historically, even in the 1930s with older materials such as catgut [4]. Concern that surgical knot technique may adversely influence its security is not new; Herakles wrote regarding technique in ancient Greek surgical texts [5].

Suture material	Number of knots tiedwith suture material	Number and proportion of knots that slipped n (%)	Mean length of slippage of knots tied with each suture material mm, and proportional increase in length of suture material held within knot post slip (%)	Lower 95% CI of mean length and mean proportion of slippage mm (%)	Upper 95% CI of mean length and mean proportion of slippage mm (%)	Median slippage mm
2/0 polyglactin(Vicryl)	90	71 (78.9%)	24.2 (136.0)	18.6 (104.0)	29.8 (167.0)	14
4/0 poliglecaprone 25(Monocryl)	90	60 (66.7%)	15.5 (108.0)	10.9 (73.8)	20.2 (142.0)	4
3/0 polydioxanon(PDS)	90	63 (70.0%)	19.1 (119.0)	13.6 (83.0)	24.5 (154.0)	8.6
1 nylon(Ethilon)	90	70 (77.8%)	34.9 (213.0)	28.6 (173.0)	41.2 (252.0)	27.7

Table 3: Number of knots tied with each suture material, proportion of each that slipped on testing, mean degree of slippage in mm and proportional increase in amount of suture material held within each knot after slippage (%), for each suture material and 95% CI.

Implications for Oncological Therapy

Surgical treatment of solid tumors can be the most challenging surgery. Success requires careful and skillful dissection and craft. Though we can now employ a variety of tools to aid such surgery, from robots to stapling devices, we still need to rely on simple techniques, including suturing and ligation of vessels, requiring secure knots to achieve these. Our initial study has demonstrated that less than meticulous techniques can produce reliably insecure knots, rather than the secure knots we would hope for.

Given the increasing and complex technology being developed and implemented for oncological surgery, a great deal of effort is directed to instructing surgeons in the use of these, and in maintaining skills in their use. However, we also need to equip surgeons in training with the basic skills such as formation of secure knots, and consider maintaining the basic skills of those already trained, so that they retain and employ those simple, but essential skills. Even the most complex surgical procedure could be considered to be a set of simple manoeuvres and steps, but many in number. Success relies on each one being performed meticulously. In an increasingly technological working environment, we may need to reconsider the importance of the simple steps, such as how to tie a secure knot, even in the most awkward location, and how to do this reliably.

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