Clinical application of safe knots

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No conflicts of interest
What are our clinical decisions

• Choice of suture material
  • Mono-multifilament resorbable or not thickness

• Choice of First knot: Approximation of tissues with traction
  • Fascia – myoma

• Choice of knot sequence: secure <-> some sliding <-> slide to open
  • Which forces are needed? >10 N > 50 N >120 N
  • For how long?

• How to cut the suture tails? short or long: at 1, 5 or 10 mm
  • Knowing that longer tails = more adhesions
Suture material: Clinical experience

- Clinical experience without understanding but with safety margins probably insecure knots mistaken for insufficient tensile strength
  - For ureter: 4.0 resorbable
  - For bowel: 3.0 resorbable
  - For fascia & vaginal cuff: 0 or 1 resorbable sutures
  - For promontofixation: non resorbable 2.0

- We know the breaking forces of sutures
  - 4.0 resorbable 30 Newton
  - 2.0 resorbable 80 Newton
  - 0 resorbable 110 Newton
  - 1 resorbable 150 Newton

- We know the resorption/hydrolysis of sutures
  - After 7 days remains 50% of the initial tensile strength / varies with suture
Basic concepts to define knots and sequences

- Type of knots
  - Half hitch - half knots
  - Throws: 1-2-3
  - Rotation:
- Knot sequences
  - Types of knots
  - Rotation Sequences
- Technique
H-S Transformation = friction

- H1 -> S
  - 5 N
- H2 -> S2
  - 10 N
  - S2: Always bad
- H3 -> S3
  - 18 N
Rotation

• Half knots
  • Symmetric = 1 plane
  • Asymmetric = 2 planes 90°

• Half hitches
  • Asymmetric: slides better

• Symmetric knots
  • Same rotation on same thread
  • Alternative rotation on alternative ends (bimanual knot tying)
What is the Best Surgeon’s Knot? Evaluation of the Security of the Different Laparoscopic Knot Combinations

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Which Knots Are Recommended in Laparoscopic Surgery and How to Avoid Insecure Knots

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J Minim Invasive Gynecol 2019
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Fig. 1

(A and B) Symmetric (A) and asymmetric (B) sequences of 2 single-throw half knots. (C and D) A sliding sequence (C) and a blocking sequence (D) of 2 half hitches. (D and E) Final knot combination of half hitches and a secure 3-throw half knot followed by a symmetric 2-throw half knot.
Clinical choices

• First knot

• Knot sequences
1th knot: forces to open

- Alternatives
  - H1 7.1 + 0.9 N
  - H2 10.0 + 2.0 N
  - H3 18.8 + 2.8 N
  - SSa >20 ?
  - SSs >20 ?

- Knot and tissue memory: maintain traction >2-3 sec

- Clinical translation in endoscopic surgery eg myoma
  - H3  H2  SS
Safe-unsafe-Dangerous - is a probability

- Newton
- H1H1a
- H1H1s
- H2H2s
- H2H2a
- H3H2a

% of knots that open

- <1
- 1-5
- 6-10
- 11-15
- 16-30
- >30
- Break
Opening is a probability

What is good enough?

- <5 dangerous
- 10-80 ?? -where
- 100% break : safe
- Sliding -> Break
Half hitches (S) and half knot (H) combinations tested. Following the knot base composed of 2 knots, additional knots were added up to 5 knots or until a secure knot combination, defined as a combination that never opened below 30 N and indicated in dark green, was obtained. Unsecure knots are indicated in shades of red. The thickness of the circumference of the circles indicates the number of throws of the knot combination. Secure knot combinations require 4 or 5 throws and 2 to 5 knots.
Breaking force

What is good enough?

• Very small SD

• Overall very similar

• Asymmetric slightly higher = angulation
Knot reorganisation and angulation

Fig. 4
Reorganization of knots. A 3-throw half knot followed by a symmetric or an asymmetric 2-throw half knot (A and D) become reorganized during traction (B and C) and later (E and F).
Destabilisation + Reorganisation during traction if not tied strongly
Why this variability?

- Knot reorganisation during traction
  - Safe 1  H2H1sH1s S Sb
  - Safe 2  H2H2   H3H3
  - Safe 3  SS SbSbSb
- Tying forces and memory
- Knot destabilisation during suturing
  - Technique : short end
  - Technique : Base
  - Technique : bimanual
  - Technique : no short sutures
Tying forces: more is better

Opening and breaking of H2H1sH1s knot combination using dry polyfilament 2-0 polyglactin 910 (PP) or dry 2-0 monofilament (MS), tied at high of low traction. Security of knots increases when individual knots were tied with high traction (p < .02), and for polyfilament sutures (p < .001). Monofilament sutures tied with moderate traction result in 5% to 10% dangerous knots. Breaking forces (M and SD) were significantly different between sutures and when tied with higher forces. The colors indicate in shades of red opening at <1 N, 1 to 5 N, and 6 to 10 N, in yellow opening at 11 to 15 N; and in shades of green opening at 16 to 30 N or >30 N, or break.

**H2H1sH1s**

**Fig. 2**

**Fig. 3**

Opening and breaking forces of different knot combinations when made with intra- or extracorporeal suturing with higher tying forces. Sequences of asymmetric half hitches SS9SS9, SS99SS9, SS999, and SS999999 were evaluated. Security of knots was higher when individual knots were tied with higher traction using extracorporeal knot tying (p < .001). The colors indicate in shades of red opening at <1 N, 1 to 5 N, and 6 to 10 N, in yellow opening at 11 to 15 N; and in shades of green opening at 16 to 30 N or >30 N, or break.
Destabilisation

Fig. 4

Opening and breaking of H2H2a knot combination using dry polyfilament 2-0 polyglactin 910 (PP) tied bimanually and monomanually by experienced surgeons and by trainees who had not yet fully completed their knot-tying learning curve. Security was higher (p<.000) when performed by an experienced surgeon. Monomanual knot tying by a less experienced surgeon resulted in 96% knots that opened at less than 3 N. The colors indicate in shades of red opening at <1 N, 1 to 5 N, and 6 to 10 N; in yellow opening at 11 to 15 N; and in shades of green opening at 16 to 30 N or >30 N, or break.

of H2H1aH1s knot combination using dry polyfilament 2-0 polyglactin 910 (PP). Security of knots is less N when sutures are very short (10 cm) in comparison with sutures of normal length. The colors indicate in shades of red opening at <1 to 10 N; in yellow opening at 11 to 15 N; and in shades of green opening at 16 to 30 N or >30 N, or break.
H2 -> S2 always a problem

- S2 H1s  S2 H1a
- S2 H2a
- S2 H2s reasonable

I have seen +++ during live surgery
Recuperation of S2S1a and S2S2a, 2 highly insecure knots, with an SSb or SbSb (p = .03). However, S2S2 followed by SSb and SbSb still has 3% that opened at less than 5 N and 2.5% at less than 10 N, respectively. The colors indicate in shades of red opening at < 1 N, 1 to 5 N, and 6 to 10 N; in yellow opening at 11 to 15 N; and in shades of green opening at 16 to 30 N or >30 N, or break.
Knot sequences: secure and less adhesions

• What is secure
  • 0% less than 50-100 N
• Sequences
  • H2H1sH1s S Sb
  • H2H2 H3H2a
  • SS SbSbSb
• Short tails – adhesions
  • H2H2SSb H3H2a
  • SS SbSbSb

Correct technique – no destabilisation
• Base - horizontal - gladiator
• 1 Short end – pull long end
• Avoid short sutures
• For H2H2 H3H2 bi-manual
• Ty with force
• Respect memory of suture
How to suture and tying a knot

- **Ergonomy – stability**
  - Fingers-hand-shoulder
  - Angle upper-lower arm >90°
  - Upper arm close to the body

- **Suture with the knot in mind**
  - Right->left or left->right  
    R->l: 1\text{th} knot untwist  2\text{nd} knot: ok
    l->R: 1\text{th} ok  2\text{nd} knot bimanual or long tread
  - Up->down or down->up  
    U->D: entrance++  D->U : exit ++
  - Tissue : do not strangulate ; approximate > blood pressure
    = decision of first knot H2 H3 or SS
    avoid destabilisation of first knot
How to suture and tying a knot

- The first knot
  - H2 H3 or SS do not strangulate
  - SS(S) for running sutures since traction in 1 direction
- Right sequences for a stable knot
  - avoid destabilisation of first knot
    Tail should be short - pull the long end – base always visible
    Short sutures is nice sport but wrong technique
    Tie with force for more than 2-3 sec
  - Speed = do not re-grasp between knots
    Right->left 1th knot clockwise rotation= untwist clockwise – short tail
    Left -> right : bimanual
- Running sutures : SSS with the double loop as passive end
MONOMANUAL AND BIMANUAL TECHNIQUE
Symmetric and Asymmetric
the influence of rotation
Clock and counterclockwise
Rules updated for different sutures

- Work in progress
- = article 3
Needle holder

• Round -> turn

• Hold with fingers
Clinical conclusions

• We exaggerated safety margins because we did not understand

• Understanding knot sequences - destabilisation – knot security leads to
  • Thinner suture material  eg  1 -> 2.0
  • Shorter tails but only a few knots have no sliding H3H2a  SSSbSbSb
  • Less accidental openings
  • Less adhesion formation

• Therefore
  • Start with H3 or SSs
  • Learn correct suturing techniques which avoids destabilisation
  • Use correct sequences
  • In doubt, add SSb
HALF-KNOT KNOT’S COMBINATION
5 THROWS

BLOCKING

H2H1aSSb