The effects of double-gloving upon the quality of knot tying; an acquired skill that is essential to good surgical practice

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Abstract

Double-gloving – the practice of wearing two pairs of gloves to carry out operative procedures – is endorsed by a number of healthcare authorities worldwide, based upon compelling evidence demonstrating that it protects patients and healthcare workers from transmission of blood-borne diseases. Despite the widespread recommendations, the adoption of this practice amongst surgeons remains limited, based upon anecdotal reporting that double gloving leads to impaired dexterity and sensation. To date, however, there has been no evidence to show that double gloving affects surgical skills. This is the first study to formally investigate and experimentally demonstrate the effect of double gloving upon the quality of knot tying – an essential surgical skill. 63 practising general surgeons tied a total of 1466 knots, under single-gloved and double-gloved conditions, using monofilament and multifilament braided sutures, at 2 different gauges. The mechanical strength of the knots were determined by tensile testing, and each knot was given a Knot Quality Score; a validated assessment of knot quality. The results obtained in this study have demonstrated that double-gloving impaired knot quality for all suture types. On the basis of this study we would recommend that surgeons consider the potential adverse effect on the quality of knot-tying, and that they identify appropriate operative strategies to ensure that patient safety is not compromised.

Introduction

The effect of double gloving upon surgical skills remains unclear. Double-gloving – the practice of wearing two pairs of surgical gloves to perform operative procedures – has been shown to reduce the risk of transmission of infectious organisms between the patient and the surgeon, thereby protecting both groups.[1, 2] A recent Cochrane review concluded that the evidence to support the practice of double gloving in the prevention of percutaneous exposure incidents in surgery, is sufficient enough to render further research into benefits of the practice unnecessary as double-gloving significantly reduces the risk of inner glove perforation, and of blood-stains on the surgeons' hands.[1] On the basis of this evidence, double gloving is recommended by a number of healthcare authorities worldwide. These include the UK Health and Safety Executive,[3, 4] whose guidance is issued as part of the implementation of the European Council Directive on prevention of sharps injuries in the hospital and healthcare sector.[5] EU Member states have been obliged to implement the directive into national legislation since May 2013.[4] The American College of Surgeons (ACS) has formally recommended universal adoption of double gloving since 2007, although that recommendation does carry the caveat that the surgeon may choose to forego this safety measure in delicate operations where it may compromise the safe conduct of the operation.[6] Double gloving is also recommended in guidelines issued by the Centers for Disease Control and Prevention in the USA,[7] and by the Australian Commission for Safety and Quality in Healthcare.[8] It is important to note that the advice from the Cochrane review is given on the basis that there is no indication that wearing more than one layer of gloves compromises sensitivity of the fingers.[1]

Despite the widespread recommendations to double-glove, there is only limited compliance with the advice, with surgeons citing impaired dexterity and impaired tactile feedback as reasons not to double-glove routinely.[2,6] Many surgeons only double-glove when they know or suspect the patient to be a carrier of a transmittable blood-borne disease.[2] This inconsistent approach of only double-gloving in certain situations may introduce variability into surgery, such as knot tying, with potential risk of impaired performance.

Although there continue to be publications regarding both the protective benefits of double-gloving and surgeons' limited compliance with the practice, there is a lack of objective data, to investigate how double-gloving may affect this crucial surgical skill.[2, 9-11] Findings from a small number of studies carried out to investigate the effect of double-gloving upon touch sensitivity and dexterity are equivocal; the evidence from these studies is compromised by either dependence upon anecdotal reporting, or the use of tasks that do not directly relate to surgical skills.[12-14]

Knot tying is one of the first skills a surgeon has to master, and good quality knot tying remains fundamental to surgical practice throughout a surgeon's career. Knot tying is a skill that requires a combination of fine motor control, dexterity, and tactile feedback; which may be impaired by double-gloving. There may be greater compounded effects from the impact of all these skills being relevant simultaneously during knot tying. With the aim of conducting a study with direct

relevance to the current day-to-day surgical practice, we investigated the effect of double-gloving upon the quality of knot tying.

Materials and Methods

Participants

Surgeons and surgeons-in-training, attending the Association of Surgeons of Britain and Ireland conference, 2010, volunteered to participate. Participants were required to either be surgical trainees with regular involvement in operative surgery, or fully qualified (including retired) surgeons. Participants also provided basic demographic data (gender, hand dominance, grade of training, years of experience) and in addition were asked to rate the frequency with which they double-glove as never, occasionally, or always.

Knot tying

Participants were randomly allocated, by computerised randomiser, to tie knots with double-gloves, followed by single gloves, or vice versa. For double-gloved conditions, participants wore gloves specifically designed for double-gloving. Under double-gloved conditions, participants wore gloves that are a half size larger than the outer pair, as per manufacturer's recommendations.

Each participant tied three knots for each of the four suture types under both gloving conditions, yielding 24 knots per participant; Vicryl 2.0, Vicryl 4.0, Prolene 2.0 and Prolene 4.0. Participants were instructed to tie knots with three throws for Vicryl, and five throws for Prolene. The sequence in which each material was used was generated by a computerised randomiser, and printed onto a piece of card attached to the knot tying jig, to instruct the participant which order to use the materials in. Knots were tied onto pseudotissue (a silastic loop of 3mm diameter), mounted onto a fixed knot-tying jig. When the participant had completed the task, the pseudotissue was removed from the jig,

with the tied knots in situ, and placed into a sealed envelope, along with the participant's demographic data. Any participant who did not complete the demographic data or tie fewer than 75% of the knots requested was not included in the analysis.

Assessment of knot quality

The knots were removed from the pseudotissue by stretching the tissue, allowing the knots to be slid undisturbed easily from the tissue, without putting the tied knot under any mechanical stresses. Each knot was suspended between high tensile hooks and subjected to distraction force to the point of failure using a Nene tensile tester, with a load cell of 500 N, running at 10mm per minute giving a reading of the force required to distract the knot every 0.01mm. To establish comparative values for each material, and to be able to calculate a knot quality score for each knot, 10 untied samples of each material were stressed to the point of breaking, using the same settings on the tensile tester.

A modified Knot Quality Score (KQS)[15-17] was calculated for each knot using both the maximum force required for the knot to fail, and the integrated force of the knot using the formula:

$$KQS = \frac{\text{Breaking/slippage force of knot} \times \text{average force through knot over 1mm distraction}}{\text{Breaking/slippage force of} \times \text{average force through suture over 1mm distraction}}$$

Statistics

Data are presented as means (standard error of the mean). Groups were compared using the unpaired t-test. A p value of <0.05 was considered significant.

To test the effect of participant factors on KQS, linear logistic regression modelling was performed. During modelling, an odds ratio (OR) of >1 indicated an increased knot quality. Number of years working was entered as continuous variables, and participant as a nominal variable; gender, hand dominance, normal use of double-gloving, and use of double-gloving on a particular knot tie were added as dichotomous variables. The factors were all initially entered at the univariate level. Those variables significant at $p<0.10$ at the univariate level were candidates for selection in a multivariate regression model. A forward stepwise selection was used retaining terms if the variable retained significance at $p<0.10$.

Odds Ratios were calculated for each suture type using linear univariate analysis. Data were analysed using SPSS 20.0 (SPSS Inc., Chicago, Illinois).

Results

A total of 1466 knots were tied by 63 participants (49 male), giving 97% completion. Only four participants were left-handed. Eleven participants (17.5%) never double-glove, 39 (61.9%) double-glove occasionally and 13 (20.6%) always double-glove. Biogel Surgeons' gloves were the preferred brand of 91% of participants.

Failed knots

Only 43 knots (2.9%) were of insufficient quality to be mounted on the tensile tester. These were counted as failed knots (Table 3). There was no significant difference between failed knots tied by either gloving technique.

1mm distraction.

Less force was required to achieve 1mm distraction for the knots tied under double-gloved conditions compared to single-gloved conditions (Table 2), however the difference for Prolene 4.0 did not reach significance ($p=0.066$).

Knot quality score

The KQS was lower under double-gloved conditions for all suture materials (Table 1). The difference in KQS when comparing all sutures combined was significant ($p=0.001$).

There was no different in the KQS of the double-gloved ties between those who routinely double-gloved and those who did not ($p=0.640$).

Univariate and Multivariate analysis

The only factors remaining significant in the model were inter-participant differences and the whether the participant used single or double gloves (Table 4). When the OR was examined by suture type there was shown to be an overall reduction in KQS by 20% using double gloves for all suture types, ranging from 13-33% (Table 5) The OR indicates that double gloving reduced the KQS by 24% overall and, as one might expect, when the finer 4'0 suture was used knot quality was reduced by as almost 50% (95% CI 13-93%) (Table 6).

Discussion

This is the first study to investigate the effects of double-gloving upon the quality of knot tying, an acquired skill that is essential to good surgical practice. Knot tying requires fine motor control, dexterity and tactile feedback; it is performed by surgeons on a regular basis, and is a reproducible skill. The study design also considered whether double-gloving was more likely to influence knot tying with monofilament or braided material, and materials of different gauges. In the design of this study, in addition to recruiting a high number of practising surgeons, we aimed to enable participants to tie knots that mimicked real-world knots as closely as possible. All of the suture material was of types that the majority of surgeons use on a day-to-day basis, and the gloves were the preferred brand of the overwhelming majority of participants.

The results provide experimental evidence that double-gloving has significant negative effects upon the quality of knot tying. The KQS, has been described as a comprehensive assessment of knot quality[16]. This study has demonstrated that double-gloving significantly reduces the KQS, and significantly reduces the amount of force required to distract the tied knot by 1mm.

The majority of participants in this study either never double glove, or do so only occasionally, for cases perceived to be high risk. Double-gloving is therefore an uncommon working condition for most surgeons; this might explain the observed effect that double-gloving impairs knot-tying, although there was no

evidence to support the fact that regular double glovers tied better quality knots than single glovers.

The logistic regression model shows that the most significant variable to affect knot quality is variation between individual surgeons, with double-gloving being the next most important factor. No other factors were shown to significantly influence knot quality. When considering a skill such as knot tying, it would be expected that inter-individual variation would be the most significant factor. The logistic regression model confirms that double gloving also has a significant effect upon quality of knot tying, even when inter-individual variation is taken into account.

Having demonstrated that double gloving impairs knot tying, we recognise the importance of interpreting these findings from a clinical point of view. There are many factors that affect the chance of knot failure, including vessel size, calcification, surrounding tissues and depth of tying. However the OR between the quality of the knots produced by single gloving rather than double-gloving suggest there may be as much as a third reduction in quality of some sutures types, and this is within ideal tying conditions.

The benefits of double gloving from a risk reduction point of view are well documented, and form the basis of formal recommendations for surgeons to double glove[1, 3-6]. The findings of our study suggest that double gloving, particularly the practice of only double gloving occasionally, may compromise practice. The American College of Surgeons' statement on sharps safety[6] acknowledges that double gloving has not received widespread acceptance by surgeons, and suggests that a period of adaptation is required to become used to

the practice. In view of the compelling evidence to support the benefits of double gloving it is reasonable to suggest that the ACS recommendation of a period of adaptation is undertaken, and that the practice is endorsed from the very early years of surgical training. If surgeons are made aware that double gloving may compromise knot tying, and that double gloving is likely to have a learning curve, they will be in a position to modify practice, and therefore minimise any potential risk to patients.

Table 1 Mean KQS values for each suture type comparing single gloving to double-gloving. P values calculated using unpaired T test.

	Single (SEM)	Double (SEM)	P
Vicryl 2.0	0.715 (0.04)	0.571 (0.038)	0.01
Vicryl 4.0	1.375 (0.084)	1.139 (0.059)	0.022
Prolene 2.0	1.408 (0.044)	1.265 (0.049)	0.029
Prolene 4.0	3.252 (0.102)	2.860 (0.089)	0.004
All sutures	1.677 (0.501)	1.460 (0.044)	0.001

Table 2 Mean force (N) required to distract the suture material 1mm for each suture type comparing single gloving to double-gloving. P values calculated using unpaired T test.

Average force 1mm	Single (SEM)	Double (SEM)	P
Vicryl 2.0	6.21 (0.204)	5.59 (0.197)	0.029
Vicryl 4.0	5.14 (0.15)	4.65 (0.15)	0.021
Prolene 2.0	6.12 (0.15)	5.56 (0.16)	0.01
Prolene 4.0	5.17 (0.11)	4.90 (0.10)	0.066
All sutures	5.67 (0.08)	5.18 (0.08)	<0.001

Table 3 Number of knots that were unable to be tested due to the poor quality but suture type and single or double gloving

Number of failed knots	Single	Double	P value
Vicryl 2.0	5/185	8/185	NS
Vicryl 4.0	7/181	6/182	NS
Prolene 2.0	2/187	8/186	NS
Prolene 4.0	5/180	2/180	NS
All sutures	19/733	24/733	NS

Table 4 Univariate and Multivariate analysis of factors which may have an effect the KQS.

	Univariate analyses				Factors remaining in the model			
	OR	95% CI		p	OR	95% CI		p
Participant	0.996	0.998	0.994	<0.001	0.996	0.998	0.994	<0.001
Gender (Male)	1.158	0.980	1.369	0.084				
Years of working	0.999	0.993	1.005	0.748				
Dominance (Right)	1.129	0.862	1.477	0.379				
Preference to DG (Do not routinely DG)	1.018	0.865	1.198	0.830				

Double-gloving (Single gloving)	0.805	0.706	0.919	0.001	0.807	0.708	0.919	0.001

Factor in brackets are the reference factor for dichotomous variables
OR – Odds ratio; CI – confidence interval; DG Double-gloving

Table 5 Univariate analysis of the effect of double gloving on the KQS

	OR	95% CI		P
Vicryl 2.0	0.866	0.776	0.966	0.010
Vicryl 4.0	0.790	0.645	0.966	0.022
Prolene 2.0	0.867	0.761	0.986	0.029
Prolene 4.0	0.676	0.518	0.882	0.004
All sutures	0.805	0.706	0.919	0.001

Table 6 Multivariate analysis of the effect of double gloving on the KQS

	OR	95% CI		P
Vicryl 2.0				
Double Gloving	1			0.010
Single Gloving	1.155	1.035	1.289	
Vicryl 4.0				
Double Gloving	1			0.022
Single Gloving	1.266	1.035	1.550	
Prolene 2.0				
Double Gloving	1			0.029
Single Gloving	1.153	1.014	1.314	
Prolene 4.0				
Double Gloving	1			0.004
Single Gloving	1.479	1.134	1.930	
All sutures				
Double Gloving	1			0.001
Single Gloving	1.242	1.088	1.416	

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