Surgeon perspectives on alternative nerve repair techniques

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Abstract

Background Over the past five decades, microsuturing has been established as the “gold standard” for nerve repair. Alternative techniques such as fibrin glue, protein “welds”, and nerve connectors have been met with variable enthusiasm. While advancements in this area continue, there is little data on surgeon attitude and acceptance of these new techniques. **Methods** A short questionnaire was electronically distributed to the members of the American Society for Surgery of the Hand and the American Association of Hand Surgery. Survey questions ascertained demographic information of participants (specialty, years in practice, practice setting, etc.), attitudes about current techniques (what techniques currently used, why, etc.), and attitudes about new techniques (openness to trying, factors that would persuade for/against, etc.). The surveys were distributed and administered online. Data gathered from responses was analyzed looking for general trends and stratified based on demographic data.

Results The majority of responders still consider microsuturing as the gold standard for primary nerve repair, and it is by far the most utilized technique. However, over 90 % also reported that they either currently use or would consider using alternate techniques. Common barriers to utilizing alternate techniques included lack of data regarding outcomes and unfamiliarity

with new techniques. Only 40 % of responders considered metal as safe around nerves, but most consider absorbable polymers safe. None of the underlying demographic variables including years in practice, number of nerve repair surgeries performed per month, practice setting, or specialty affected these general trends.

Conclusions Most surgeons performing nerve repairs prefer suturing as their primary repair technique, but a vast majority is open to utilizing alternate repair techniques, especially those that improve outcomes with a faster and easier procedure. While not able to direct clinical practice guidelines, this study can be used to direct focus and funding of further alternate nerve repair techniques.

Keywords Nerve repair · Surgeon preference · Alternative nerve repair techniques

Introduction

The last major advance in nerve repair technique occurred over 50 years ago with the development of microsurgical equipment and instrumentation. Microsuture as a means of holding co-apted nerve stumps together was established as the “gold standard” at that time and remains so today [11].

Alternative repair techniques have been introduced with variable degrees of success and acceptance amongst surgeons. Current alternate techniques include fibrin “glue” applied as a cocoon around approximated nerve ends, use of laser-assisted protein “welds,” and, more recently, the use of nerve-connecting conduits [7, 16–18, 20]. Though in most of these techniques, the use of sutures (and the expense, time, and skill associated with their usage) is not avoided, the overall number of sutures is decreased and suture placement may be directed away from the critical nerve end.

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As researchers continue to refine these techniques and to pursue new ideas and strategies, there is little data on peripheral nerve surgeon attitudes towards these advances. The purpose of this study was to solicit opinions on current attitudes among hand surgeons regarding alternative nerve repair techniques. While innovation will most likely continue regardless, understanding perceived satisfaction and prejudices regarding current repair techniques as well as surgeon desire for future nerve repair tool development can help direct research money and resources.

Materials and Methods

After appropriate review by our institution's investigative review board, a short questionnaire was distributed to the members of the American Society for Surgery of the Hand (ASSH) and American Association of Hand Surgery (AAHS) ($n=2573$) during the months of April and May 2013. Participants received an invitation to participate in the survey via electronic mailing followed by one reminder email 2 weeks later. The mailing contained a link to the survey (hosted by kwiksurveys.com), which allowed both the administration of the questions and collection of the data electronically. Practicing hand surgeons who were members in either the ASSH or AAHS and had supplied these organizations with email addresses were included. Incomplete, duplicate, and incorrectly answered surveys were excluded.

Demographic questions included primary surgical focus and clinical setting, years in practice, Certificate of Added Qualification (CAQ) Hand, and average number of nerve repair surgeries per month. Practice-focused questions included current methods preferred for primary nerve repair, willingness to try alternate techniques, barriers to utilizing alternate techniques, and qualifications of a particular alternate technique necessary for them to be considered (see Electronic Supplementary Material 1 for detailed questionnaire).

Results

Requests for participation were sent to a total of 2,573 hand surgeons. Members of both participating organizations received only one invitation. A total of 271 (10.5 %) completed the questionnaire within criteria. Most responders were orthopedic (68.5 %) or plastic (24.4 %) surgeons with a little less than half (44.2 %) holding a CAQ Hand. About half (51.9 %) were in private practice versus 43.7 % in public or teaching hospitals. The large majority (78.7 %) reported performing fewer than five nerve repair surgeries per month. When ranking the repair techniques most currently used, sutures alone was easily the most preferred, being ranked number one by 80.8 % of responders. Sutures alone was also identified as the

gold standard technique for primary nerve repair, and 73.7 % agreed that sutures through nerve ends are a critical component of a proper nerve repair. Other commonly utilized repair methods ranked included using nerve connectors secured by sutures (ranked second), fibrin glue alone (third), and nerve connectors secured by fibrin glue (fourth). Of those that use sutures alone, 94.7 % responded that either they already use or would consider using alternate techniques, compared to only 5.2 % that would not. These results were similar when stratified based on years in practice (Fig. 1) or practice setting (academic vs. non-academic). Of those not currently using alternate techniques, 47.9 % were completely open to using alternate techniques. The rest identified wanting more data on outcomes (28.6 %) and unfamiliarity with alternate techniques (14.5 %) as barriers to using them (Fig. 2). The most commonly identified factor in choosing an alternate technique was improved outcomes (32.2 %). Regarding potential materials for nerve repairs, 77.7 % felt that absorbable polymers around nerves are safe, but only 40.9 % felt that metal around nerves is safe (Table 1).

Discussion

Our survey found that modern hand surgeons consider microsuturing of co-apted nerve stumps as the accepted gold standard in primary surgical nerve repair. This agrees with previous studies that show that this standard has been maintained since the development of these techniques [11]. However, this standard is not without its shortcomings. The placement of microsutures requires significant practice and skill, is quite time-consuming, and utilizes a significant amount of operating room resources [27]. Suture size, the number of sutures, and suture placement all remain continued sources of controversy amongst peripheral nerve surgeons [2, 8–10, 13, 21]. In addition, suture material has been associated with the generation of scar tissue though the exact detrimental effects, if any, on axon regeneration are not known [13]. Although suturing in some form remains widely accepted, alternate techniques are continually being developed with hopes of improving outcomes and surgical efficiency [7, 16–18, 20].

Though we would have predicted that the most popular alternative technique to sutures would be the use of either commercially available or autologous fibrin glue applied as a cocoon around approximated nerve ends [20], our survey found this technique to be the third most often utilized technique among responding hand surgeons. The main advantages of this tool include ease and speed of application. A less experienced microsurgeon can achieve equivalent results as an experienced microsurgeon when performing neurorrhaphy with fibrin glue in a mouse sciatic nerve model [27]. Though maintaining alignment between fascicular groups when not first establishing alignment with sutures can be challenging,

Fig. 1 Nerve repair preferences stratified by years in practice

the main concern with fibrin glue neurorrhaphy is a lack of holding strength. Several animal studies have reported dehiscence of co-apted nerves [3, 15, 23, 26], and a biomechanical study demonstrated resistance to gap formation, but no significant augmentation of holding strength over sutures alone [12]. The use of commercially available fibrin glues in nerve repair is not approved by the Food and Drug Administration.

Other ideas that have been pursued either experimentally or clinically include the use of laser-assisted protein “welds” and,

more recently, the use of nerve connectors. The laser technique essentially involves holding the nerve ends co-apted, applying a few drops of protein (albumin) to the nerve co-aptation, and using the laser to denature the protein so that it acts as a solder. While experimentally effective [17], this strategy does not solve the high resource utilization problem and is hampered by concerns over thermal damage to the nerve associated with the laser [16, 18]. Nerve connectors are small nerve tubes used as primary repair aids in the

Fig. 2 Barriers to trying alternative techniques of nerve repair

Table 1 Raw data stratified by demographic information

Demographics	Overall	If you repair with sutures		What barriers, if any, exist?				Factors important in choosing							
		Satisfied with sutures, but would consider alternate techniques	Already use both sutures and alternate techniques	Satisfied with sutures and would not consider alternate techniques	Unfamiliarity	Require more data on outcomes	Poor previous experience	None, I am open to alternate techniques	Other	Faster procedure	Easier procedure	Lower cost	Favorable reimbursement	Reduced complication	Improved outcomes
All respondents	100 %	56.90 %	37.80 %	5.20 %	14.50 %	28.60 %	3.80 %	47.90 %	5.20 %	17.30 %	16.50 %	12.80 %	6 %	14.80 %	32.20 %
Primary surgical focus															
Orthopaedics	68.50 %	59.10 %	35.40 %	5.50 %	14.80 %	27.50 %	5.30 %	48.70 %	3.70 %	17.40 %	16.80 %	12.50 %	6.40 %	14.00 %	32.70 %
Plastic surgery	24.40 %	5.50 %	51.50 %	3.00 %	10.80 %	28.40 %	1.40 %	50 %	9.50 %	18.20 %	15.80 %	12 %	6.20 %	17.20 %	30.10 %
Neurosurgery	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other	7 %	73.70 %	15.80 %	10.50 %	23.10 %	38.50 %	0 %	34.60 %	3.80 %	11.60 %	16.30 %	20.90 %	0 %	14 %	34.90 %
Current CAQ in Hand															
Yes	44.20 %	55.80 %	39.80 %	4.40 %	11 %	29.70 %	1.70 %	51.70 %	5.90 %	16.20 %	16.20 %	12.40 %	6.70 %	14.60 %	33.10 %
No	55.80 %	59.60 %	36.90 %	3.50 %	14.20 %	26.50 %	5.80 %	48.40 %	5.20 %	18.80 %	16.50 %	12.50 %	5.30 %	14.80 %	32 %
Years in practice															
1–5 years	43.70 %	57.30 %	41.90 %	0.90 %	12.50 %	27.50 %	3.30 %	54.20 %	2.50 %	19.30 %	16.40 %	12.40 %	6.10 %	14.80 %	31 %
6–10 years	7.80 %	42.90 %	52.40 %	4.80 %	4.30 %	17.40 %	8.70 %	65.20 %	4.30 %	16.40 %	15.10 %	15.10 %	9.60 %	15.10 %	27.40 %
11–15 years	5.60 %	66.70 %	20 %	13.30 %	1.80 %	35.30 %	5.90 %	41.20 %	5.90 %	14.70 %	8.80 %	14.70 %	5.90 %	14.70 %	38.40 %
15+ years	42.90 %	58.60 %	33.30 %	8.10 %	18.90 %	29.90 %	3.10 %	40.90 %	7.10 %	15.20 %	18 %	12.50 %	4.80 %	14.90 %	34.30 %
Primary practice location															
Private practice	51.90 %	60.70 %	34.30 %	5 %	15.50 %	27.10 %	2.60 %	51 %	3.90 %	17.30 %	15.80 %	13 %	6.50 %	14.30 %	32.30 %
Public hospital	4.80 %	76.90 %	15.40 %	7.70 %	7.70 %	53.80 %	7.70 %	23.10 %	7.70 %	16.70 %	10 %	10 %	6.70 %	16.70 %	40 %
Teaching hospital	38.90 %	48.10 %	46.20 %	5.80 %	12.50 %	29.80 %	2.90 %	49.00 %	5.80 %	17.40 %	17.70 %	13.10 %	5.50 %	15.30 %	30.90 %
Other	4.40 %	77.80 %	22.20 %	0 %	22.20 %	16.70 %	16.70 %	33.30 %	11.10 %	16.00 %	20 %	8 %	4 %	16 %	36 %
Average number of nerve repair surgeries/month															
0 to 4	78.70 %	60.40 %	34.30 %	5.30 %	15.90 %	27.60 %	4.30 %	46.60 %	5.60 %	17 %	17.30 %	12 %	6.30 %	14.90 %	32.30 %
5 to 10	18.70 %	42 %	54 %	4 %	8.50 %	34 %	0 %	53.20 %	4.30 %	18.40 %	13.50 %	17 %	5 %	14.90 %	30.50 %
10+	2.60 %	57.10 %	28.60 %	14.30 %	0 %	25 %	12.50 %	62.50 %	0 %	18.80 %	12.50 %	12.50 %	6.30 %	12.50 %	37.50 %
Demographics									What is considered the gold standard technique?						
			Think suturing nerve ends together is critical?	Think Absorbable polymers around nerves are harmful	Think metal around nerves is harmful										
			Yes	No	Yes	No	Sutures alone	Fibrin Glue alone	Conduit secured with sutures	Conduit secured with glue	Conduit secured with sutures and fibrin glue	Sutures +fibrin glue	Sutures of nerve stumps but reinforced with conduit or nerve wrap		
All respondents	0.40 %	73.70 %	26.30 %	22.30 %	77.70 %	59.10 %	40.90 %	78.30 %	0 %	4.10 %	0 %	0.70 %	7.10 %	9.70 %	
Primary surgical focus															
Orthopaedics	0.20 %	73.90 %	26.10 %	20.60 %	79.40 %	57.20 %	42.80 %	80.70 %	0 %	2.80 %	0 %	0.60 %	5.50 %	10.50 %	
Plastic surgery	0.50 %	69.70 %	30.30 %	18.80 %	81.30 %	60.30 %	39.70 %	72.70 %	0 %	7.60 %	0 %	1.50 %	12.10 %	6.10 %	
Neurosurgery	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Other	2.30 %	84.20 %	15.80 %	52.90 %	47.10 %	76.50 %	23.50 %	78.90 %	0 %	5.30 %	0 %	0 %	0 %	15.80 %	
Current CAQ in Hand															
Yes	0.60 %	72.30 %	27.20 %	28.70 %	71.30 %	61.10 %	38.90 %	82.50 %	0 %	6.10 %	0 %	0.90 %	7.90 %	2.60 %	
No	0 %	73.90 %	26.10 %	14 %	86 %	55.20 %	44.80 %	75.70 %	0 %	2.90 %	0 %	0.70 %	5 %	15.70 %	
Years in practice															
1–5 years	0 %	73.50 %	26.50 %	12.30 %	87.70 %	60.40 %	39.60 %	76.10 %	0 %	1.70 %	0 %	0 %	6.80 %	15.40 %	
6–10 years	1.40 %	66.70 %	33.30 %	23.80 %	76.20 %	33.30 %	66.70 %	76.20 %	0 %	9.50 %	0 %	0 %	9.50 %	4.80 %	

Table 1 (continued)

Demographics	Factors important in choosing	Think suturing nerve ends together is critical?		Think Absorbable polymers around nerves are harmful		Think metal around nerves is harmful		What is considered the gold standard technique?						
		Yes	No	Yes	No	Yes	No	Sutures alone	Fibrin Glue alone	Conduit secured with sutures	Conduit secured with glue	Conduit secured with sutures and fibrin glue	Sutures+fibrin glue	Sutures of nerve stumps but reinforced with conduit or nerve wrap
11–15 years	2.90 %	80 %	20 %	33.30 %	66.70 %	53.30 %	46.70 %	86.70 %	0 %	6.70 %	0 %	0 %	6.70 %	0 %
15+ years	0.30 %	74.80 %	25.20 %	31.10 %	68.90 %	64.40 %	35.60 %	79.30 %	0 %	5.40 %	0 %	1.80 %	7.20 %	6.30 %
Primary practice location														
Private practice	0.80 %	74.10 %	25.90 %	20.30 %	79.70 %	58.20 %	41.80 %	79.10 %	0 %	4.30 %	0 %	0 %	4.30 %	12.20 %
Public hospital	0 %	84.60 %	15.40 %	23.10 %	76.90 %	72.70 %	27.30 %	84.60 %	0 %	7.70 %	0 %	0 %	0 %	7.70 %
Teaching hospital	0 %	72.80 %	27.20 %	24 %	76 %	57.60 %	42.40 %	75.20 %	0 %	3.80 %	0 %	1.90 %	12.40 %	6.70 %
Other	0 %	70 %	30 %	30 %	70 %	77.80 %	22.20 %	88.90 %	0 %	0 %	0 %	0 %	0 %	11.10 %
Average number of nerve repair surgeries/month														
0 to 4	0.30 %	69.90 %	30.10 %	21.20 %	78.80 %	58.40 %	41.60 %	78.70 %	0 %	3.90 %	0 %	1 %	6.30 %	10.10 %
5 to 10	0.70 %	88 %	12 %	26 %	74 %	63.30 %	36.70 %	76 %	0 %	6 %	0 %	0 %	10 %	8 %
10+	0 %	85.70 %	14.30 %	16.70 %	83.30 %	40 %	60 %	71.40 %	0 %	0 %	0 %	0 %	14.30 %	14.30 %

absence of a gap. Though the survey did not specify, “nerve connectors” can include manufactured or “biologic” conduits such as veins. Nerve stumps are placed into the ends of the short nerve tube so that their ends are approximated or only a couple of millimeters apart. Sutures are placed through the end of the tube and into the outer epineurium to maintain the coaptation [7]. With this technique, the use of sutures (and the expense, time, and skill associated with their usage) is not avoided, but the overall number of sutures is decreased, and suture placement is directed away from the critical nerve end where associated scarring is more likely to impede axon regeneration. Additional theoretical benefits related to creating a protected microenvironment around the nerve repair include the concentration of neurogenic factors at the repair site, protection from invading scar tissue [6, 7], and blockage of escaping axons (associated with persistent pain at the repair site) [4]. At least a clinical equivalency to primary suture has been demonstrated utilizing these concepts in major peripheral nerve repairs [1, 14].

We sought to assess the current attitudes of practicing surgeons with regard to these alternate nerve repair techniques. A survey of this nature can only address responding surgeons' opinions and is based in their experiences; therefore, it cannot be used to establish clinical guidelines. In addition, we required 334 responses to reach 95 % confidence within a 5 % margin of error. With our number of responses equaling 271, we could only expect a 90 % confidence interval within our population size. The 10.5 % response rate was lower than we had expected. This limitation is possibly the result of “survey overload” as a large number of electronically-based surveys are now received by each of the target physicians. In an effort to improve surgeon participation, the survey was purposely kept as short as possible though this opens the study up to criticisms regarding limited answer choices and failure to differentiate between “nerve types.” In other words, a surgeon's perspective on repairing the brachial plexus may differ substantially from their opinions regarding digital nerve repairs. Additionally, there are certainly many “non-hand” surgeons who fix peripheral nerves. The survey was limited to hand surgeons for two reasons. First, almost all hand surgeons do perform or are at least knowledgeable regarding nerve repair techniques. Secondly, though several non-hand-related specialty societies were contacted, all declined to participate. Regardless, this survey did indicate general trends concerning the attitudes of surgeons performing nerve repair surgeries with regards to traditional and alternate techniques.

When ranking which techniques they currently utilized, over 80 % of responders ranked sutures alone as their number one preferred method, again consistent with the current “gold standard”. After weighting averages, nerve connectors secured with sutures were easily the second most often utilized. After that, the differences among use frequency became less clear. Fibrin glue alone and nerve connectors secured with fibrin glue alone

ranked third and fourth, respectively, but were far below sutures alone and nerve connectors secure with sutures and not much higher than other alternate techniques or combinations of techniques. Of note, our data shows that when nerve connectors are used, they are much more often secured with sutures than with fibrin glue. In fact, fibrin glue was more often used alone than with a nerve connector.

The >94 % positive response to either being open to alternate techniques or already using them shows consensus for the acceptance of these techniques in modern practice and suggests increased utility for their advancement. The biggest deterrents to those not currently using alternate techniques were found to be lack of data and unfamiliarity with alternate techniques showing the necessity for further research and development. Not surprisingly, the number one factor that surgeons noted that would increase their likeliness to use an alternate technique is the one that improved outcomes. Other positive factors included alternate techniques using faster and easier procedures.

Perceptions regarding the use of materials around nerve repairs were interesting and somewhat counterintuitive. Polymers around nerve repairs were for the most part considered safer than metals. This is most likely in large part due to the commercial availability and subsequent familiarity of many “polymer” type nerve repair aids such as polycaprolactone and polylactic acid nerve tubes. Absorbable polymers such as these, however, have been associated with swelling or detrimental changes to the local microenvironment during resorption. Swelling can result in nerve compression inhibiting axon regeneration [5, 19], and lactic acid production during enzymatic breakdown can induce scarring [24]. Metal around peripheral nerve repairs has been scientifically questioned to a much lesser degree. Seery et al. reported that the presence of metal around nerve repairs hampered neural regeneration in a rodent model. Their investigation, however, was specifically aimed at evaluating the effects of shrapnel, and they implanted fragments from an artillery casing [25]. Payne et al., by contrast, supported the use of medical grade titanium staple-assisted neurohaphy [22]. Certainly, metal clips are routinely used in the central nervous system without untoward effects.

Conclusions

Although most surgeons performing nerve repairs currently prefer suturing as their primary repair technique, most are open to utilizing alternate repair techniques. Unfamiliarity with techniques and lack of data on outcomes are identified as barriers to utilization. Further development of alternate techniques should focus on those that improve outcomes with a faster and easier procedure. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national)

and with the Helsinki Declaration of 1975, as revised in 2008. After review by our investigational review board, informed consent was deemed not necessary.

Conflict of interests AO and BM declare that they have no conflict of interest. JI has received consultant and speaker fees from Axogen, Inc. which sells products indirectly related to the content of this manuscript.

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