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Systematic Injection Patterned-Technique of One-Per-Mil Tumescent Solution for Perforator-Based Skin Flap: Is it Better Than the Random Patterned-Technique?

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The aim of the study is to compare the systematic injection patterned-technique of 1-per-mil tumescent solution versus the random patterned-technique. Several incidences of perforator flap necrosis have been encountered with tumescent technique. Among the possible causes, the most probable cause is the injury of perforator artery due to the multi-passing needle injections. Thus, an evaluation regarding the needle injection pattern needs to be done in order to avoid necrotic flap incidence. A randomized controlled experimental study was conducted on both groins of 20 healthy Wistar stained-*Rattus novergicus* weighing 220 to 270 g. A comparison of a systematic injection pattern and a random injection pattern was performed. Three mL of 1-per-mil tumescent solution was injected subcutaneously before elevation of the islanded groin flap. Clarity of the operative field along with the size of the pedicle were recorded. The photos of survival area of the skin flap on postoperative day 7 were analyzed using Analyzing Digital Images. Totally bloodless operative field was observed in all subjects. Three out of 19 flaps in group A (15.78%) and 4 out of 18 flaps in group B (22.22%), were found to be necrotic, either total or partial. No significant difference ($P > 0.05$) was found between the injection technique groups, in terms of flap necrosis. Although the 1-per-mil tumescent technique is advantageous in a way that it provides a totally bloodless operative field, the systematic injection patterned-technique was not found to be more superior compared to the custom random patterned-multi-passing needle injection technique.

Key words: Epinephrine – Hand injuries – Injections – Perforator flap – Upper extremity

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There are only a small number of reports in the literature citing the tumescent technique applied for perforator-based flap surgery. Although this study failed to show any significant difference between the random patterned-injection technique and the systematic patterned-injection technique of tumescent solution in regards of the incidence of perforator-based flap necrosis, it opens the potential application of tumescent technique in perforator flap surgery. However, further studies are still necessary to be conducted by considering the use of bigger experimental animals before embarking into clinical setting.

Over the years, tumescent solution has come to be used for liposuction as well as various operations for breast, facial, body contouring, and hand.[1] Interestingly, surgery for the hand came later as the field of practice where tumescent solution has been replacing the tourniquet technique.[2–5] Through various epinephrine concentrations, ranging from 1:100,000 to as low as 1:1,000,000, tumescent solution has shown to have effective haemostatic effect in hand and upper extremity surgery.[2,3,6–8]

Prasetyono, who uses 1-per-mil tumescent solution, showed the effectiveness of the technique in creating safe bloodless operative field in his reports.[6–8] He has broadened the indications of the technique to be used in hand and upper extremity surgery, including perforator flaps.[7] However, in his early cases with flaps, he experienced both complete and partial flap loss.[6]

Taking flap necrosis into serious account, neither the surgeon nor the patient would be happy to experience 1 flap loss. There are some possible factors that may cause the flap to fail, especially with the perforator flap. They might include the excessive compression of perforator vessel by the solution, the injection of solution into subdermal and dermal layers,[9] and severe vasoconstrictive effect of epinephrine to the perforator vessel that leads to flap infarction. However, there are several evidence to support the safety of massive injection volume as well as the vasoconstrictive effect of epinephrine.[2–4] Thus, it is suggested that the most probable cause of the flap loss is an injury to the perforator due to the multi-passing needle punctures in the random style of injections.[6] Based on this suggestion, the current study was conducted to evaluate the technical aspect of needle injection of tumescent technique in order to avoid injuring perforators supplying blood flow to skin flaps.

Materials and Methods

An experimental study with parallel design was performed to compare the effect of systematic and random patterned-injection techniques on the survival of groin flap in 20 certified healthy Wistar strain of *Rattus novergicus*, weighing 220 to 270 g (248.68 ± 15.169 g). The groin flap, which is nourished by superficial inferior epigastric artery (SIEA), was used due to its resemblance to perforator-based skin flap. The rats were divided into 2 groups of different techniques of 1-per-mil tumescent injection. The first group (Group A) received a random patterned-injection technique, while the other (Group B) had a systematic patterned-injection technique. Randomization was performed in regards of the right and left side of the groin. With an approval from the Institutional Review Board, the study was conducted in an Animal Laboratory in December 2013.

All rats were housed in a 12-hour alternating diurnal-nocturnal schedule and received stock diet and water *ad libitum* for 7 days prior to surgery. All surgical procedures were performed with a standard aseptic and antiseptic technique. An intramuscular injection of 35 mg/kg ketamine and 5 mg/kg xylazine was performed. The rats were placed in supine position and prepared for surgeries. We designed a 3 × 2 skin flap on the bilateral groins with the projection of SIEA on its surface (Fig. 1).

One-per-mil tumescent solution, consisted of 1:1,000,000 epinephrine in saline solution and 20 mg lidocaine per 50 mL solution, was prepared. With 1-cc syringe and 27G needle, we injected 3 mL of 1-per-mil tumescent solution gently, after aspirating in every injection site to avoid puncturing any vessel. The infiltrative injection in Group A was started at a distal corner of the flap and continued randomly until the 3 mL solution had finished through 6 divided injections. Thus, every site bears 0.5 mL solution injected. On the other hand, the infiltrative injection in Group B was performed by injecting the distal, medial, proximal, and lateral corners with the equally divided 3 mL tumescent solution; every site bears 0.75 mL solution injected. Concerning the extremely small flap area in both groups, the needle was not pushed forward as we wanted the solution to naturally move forward inside the tissue.

Ten minutes after the last injection, we elevated the flap. The sizes of the left and right SIEA were then recorded. The clarity of the operative field was subjectively evaluated and categorized into the

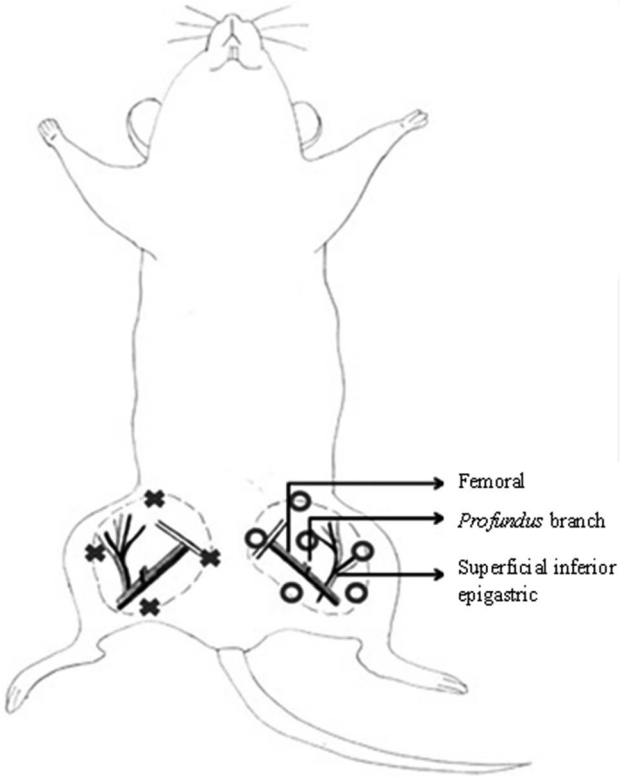

Fig. 1 Groin flap design. Projection of group A injection (○); projection of group B injection (×).

following three categories: totally bloodless, minimum bleeding, and acceptable bleeding.[2] Totally bloodless category describes a bloodless operative field that is similar to the operative field achieved when using a pneumatic tourniquet. Minimum bleeding is defined as the presence of bleeding in the operative field that does not hinder the recognition of the anatomical structures; frequent blood sweeping with gauze is not needed. Acceptable bleeding represents a condition that needs more frequent blood sweeping in order to preserve the anatomical recognition; the condition still does not hamper complicated surgical procedures.

The flap was immediately sutured back with 5-0 nylon sutures. Immediate postoperative flap were recorded with an automatic mode of picture taking by Canon IXUS 210; 14.1 MP digital camera (Canon Inc, Tokyo, Japan) from a 30-cm distance. The animals were kept alive for further observation on the flap outcome.

Seven days after surgery, the survival area of the skin flaps was observed. The images that were taken with the same camera and technique as in the immediate postoperative imaging, were then analysed by an independent assessor. Any necrotic and total flap areas were measured as square centimetres and compared by Analyzing Digital Images software. Hypothesis was tested with χ^2 test, while homogeneity was tested with Shapiro–Wilk test. $P < 0.05$ was considered as statistically significant.

Results

The 20 rats in Group A and B have a mean flap area of 4.481 ± 0.3324 cm^2 and 4.336 ± 0.3711 cm^2 respectively. Both areas pose no difference ($P = 0.22$). More than 90% of the diameter of the flaps' pedicles was less than 1 mm (Fig. 2). There are 2 dropouts in this study; 1 flap of group A got accidental injury by a piece of wood, while one rat in group B died. Intolerance to the anesthesia was predicted to be the cause of death of the later.

The 1-per-mil tumescent technique resulted in totally bloodless operative field for all subjects. On day 7 after surgery, 3 out of 19 flaps in group A (15.78%) and 4 out of 18 flaps in group B (22.22%), were found to be necrotic. The result of the image analysis shows that the mean survival areas in partial necrotic flaps are 31.86% for group A and 36.59% for group B (Fig. 3). No significant difference ($P > 0.05$) between the groups was found, in terms of the number of flap necrosis (Table 1).

Discussion

Controversy in the publications of negative studies is not a new concern in health care journalism. The opposing parties may worry that the favored treatment is inferior and that negative trial reports may lower the quality of literature. They may also argue that the data are usually not so important. Furthermore, the data may receive little interest from readers. On the contrary, parties in favor may argue that at least negative trials provide some evidence and balance against the overwhelming power of positive data. In fact, studies that do not support prior hypotheses are especially important. Deciding not to publish these negative studies will only lead to unnecessary repetition of research.[10] Hence, considering the latter arguments, this research is needed to further contrasting existing data, so that surgeons who are enthusiastic about tumescent solution could know the factual experimental conditions in using it.

To be self-critical in advance, we found some limitations in this study. The first is that this study

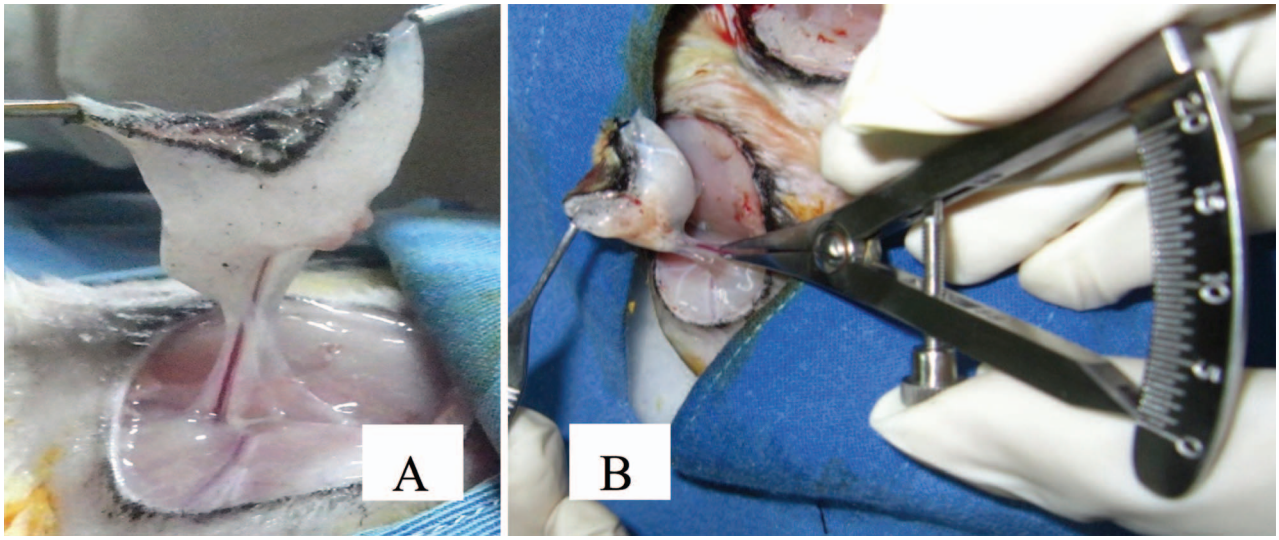

Fig. 2 The vessel diameter. (A) Flap is being elevated; (B) diameter of the pedicles was mostly less than 1 mm.

was conducted without a control group. Secondly, the injection was performed without an image-guided tool to hydro-dissect an injury-free perforator vessel. The third is the needle size was too big in comparison to the flap area. Lastly, although the rat's groin flap resembles a model of perforator based-skin flap, given the fact that the vascular pedicle is very small in caliber ($\leq$1 mm), the nature of the flap is still not a perforator type.

Although this study did not intend to delineate the action of lidocaine, we did not change the content of 1-per-mil formula that had been used previously in the clinical setting of hand surgery.[7,8] The original formula is observed as a whole entity, regardless of any possible potentiation between epinephrine and lidocaine. Nonetheless, to the best of our knowledge, there is no evidence proving lidocaine to either potentiate or inhibit epinephrine.

It is no doubt that the tumescent technique shows effective bloodless operative field in both groups, which are similar in their characteristics (Table 1). The amount of solution injected, which is considered as excessive compared to the flap area, could create a totally bloodless operative field in all flaps. In fact, this study showed the 3 mL tumescent injection resulted with waterous tissue appearance (Fig. 4). However, in the clinical setting, the concern is more to how the massive amount of solution is injected safely without injuring the vessels, which are very small in caliber, while providing comfort to the

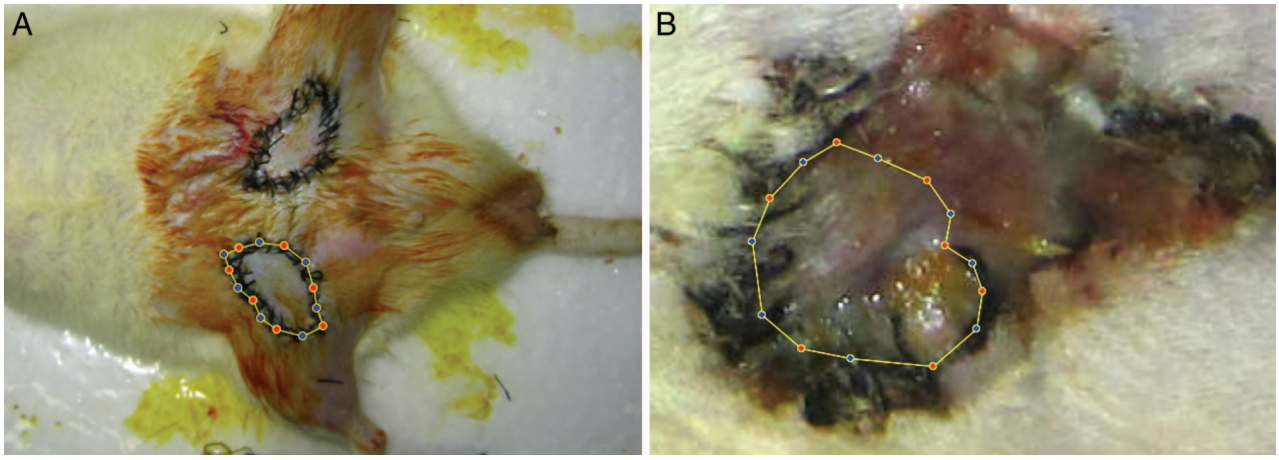

Fig. 3 Partial flap necrosis. With Analyzing Digital Images, (A) image at immediate postoperative; (B) zoomed-in image at POD-7. The survival area of partial necrotic flap in this picture is 35.03% (1.17 cm^2/3.34 cm^2 $\times$ 100%).

Table 1 Summary of experimental findings

	Group A	Group B	*P*-value
Number	19	18	
Mean of flap area (cm^2)	4.481 ± 0.3324	4.336 ± 0.3711	$P = 0.22$[a]
SIEA diameter			
1 mm	3	0	
<1 mm	16	18	
Clarity of the operation field			
Totally bloodless	19	18	
Minimal bleeding	0	0	
Acceptable bleeding	0	0	
Flap survival			$P = 0.693$[b]
Vital	16	14	
Partial necrosis	2	2	
Total loss	1	2	

SIEA, superficial inferior epigastric artery.

[a]Shapiro–Wilk test.

[b]χ^2 test.

patient. More importantly, whatever syringe device used, one must be careful for not hitting the vessel.

As mentioned earlier, the 1-per-mil tumescent solution may have shown unfavorable effect for the flap surgery; especially on the perforator-based skin flap.[6] It is believed that epinephrine causes vasoconstrictive effect,[11,12] and perhaps leads to flap necrosis, especially when the large flap is raised immediately after injection.[9] However, Atabey *et al*[13] contradictorily stated that the application of lidocaine with 1:400,000 and 1:800,000 epinephrine concentrations were found to be safe on the rats' skin flap and delaying raising time of the flaps appeared to not change the rate of flap necrosis. In our study, 7 out of 37 flaps (18.91%) were considered as losses. Although the number of flap losses is experimentally significant, no statistical conclusion could be drawn regarding the safety of this tumescent technique in flap surgery, as there was no comparative control group of flap elevation without tumescent injection.

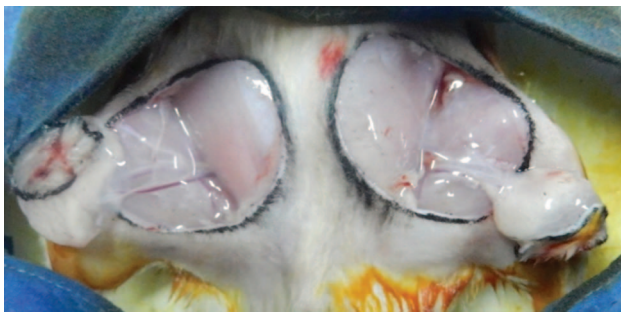

Fig. 4 Macroscopic waterous tissue appearance. The tissue looks heavily swollen after tumescent injection in this bloodless operative field.

Lalonde[2,3,14–17] performs his practice with big syringe as he has shown through his reports using 20 mL device. He changed the needle with the 27G one, which is much smaller than the original needle paired with the 20 mL syringe. Interestingly, it was said that it could give less pain to patients. However, we do not agree with the idea. In our opinion, the small needle would not be physiologic in accommodating the fluid flow from the big syringe. The 27G needle, which is originally physiologic to a 1 mL syringe, would give higher resistance when it is paired with 20 mL syringe; thus, more energy would be needed to push the piston. It would also become less controllable in terms of fluid amount during moment of injection, in which it may cause more pain to the patients whatsoever. Although the concept of "blow slow before you go"[13] or slow technique may reduce the pain, according to our best understanding, the nerve endings would be sharply overflowed by the fluid turbulence coming in from 20 mL syringe when compared to a slow blow from a 27G needle connected to 1 mL syringe. So, the pain would be greater created by the 20 mL syringe injection. A 1 mL syringe is no doubt much easier to control the flow speed of the solution being injected. The only advantage of using big syringe is that it may be faster without the need to reload the syringe frequently as in the case of using 1 mL device. So, those aforementioned points became the background of the use of 1 mL syringe for a more

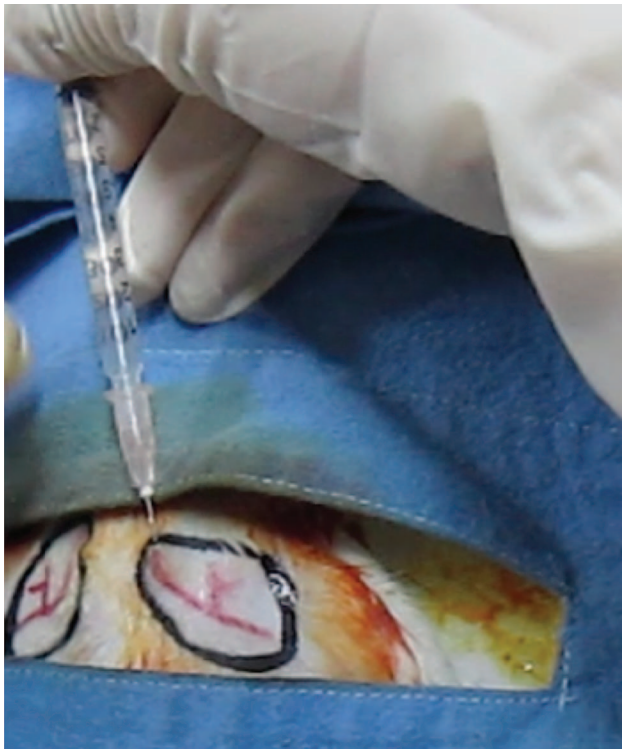

Fig. 5 Comparison between needle and the flap size. A 27G needle in comparison to the area of the flap.

comfortable tumescent injection through a restrictive number of needle entries to the tissue.

The authors believe that the most probable cause of flap necrosis is related to the perforator injury after multiple passing needle injections, as both the hydro compression and epinephrine vasoconstrictive effects are not proven.[2–4] Furthermore, the injection of solution into the subdermal and dermal layers[9] is considered as a technical flaw; hence, it is beyond the discussion. In the clinical setting, the massive volume would be infiltrated subcutaneously with a 1-mL syringe through multiple needle entries that are kept as low as possible in its frequency by upholding the reloads of the syringes as many as possible via every hole of needle puncture.

As for this study, aside from the extremely small area to work with the injection techniques and the attention on surface reflection of the vessel anatomical course, which is equal for both groups, we pointed the technical differences in between the 2 injection techniques. The differences include: (1) the entry points are more structured in group B to avoid the needle from puncturing the vessel, while the pattern of needle entry points in group A is assumed to represent the random style of needle entry points of common practice in the real clinical setting; (2) the number of needle entry points is made less in group B, which is 4 compared to 6 in group A, in order to reflect the more carefulness of the systematic pattern style. Apparently, it was found that the different techniques of injection did not affect the flap survival ($P > 0.05$). We could not be sure that the systematic patterned-technique did not cause any vessel injury, since we did not use any image-guided tools when injecting the solution. Accordingly, the 27G needle size might be too big for the flap, which has only $\leq$1 mm calibered vessel (Fig. 5). A tiny vessel may still be prone to injury whatsoever. However, the 27G needle was chosen because it is normally used in the clinical setting.

Despite the fact that the present study has several limitations, it is still meaningful because it suggests that surgeons must recognize the potential perforator flap failure with regard to tumescent technique. Besides, further studies need to be conducted to disclose the impacts of 1-per-mil tumescent solution in cellular level.

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References

1. Mustoe TA, Lalonde DH. The safe management of anesthesia, sedation, and pain in plastic surgery. *Plast Reconstr Surg* 2010; **126**(4):165e–176e
2. Lalonde D. Minimally invasive anesthesia in wide-awake hand surgery. *Hand Clin* 2014;**30**(1):1–6
3. Lalonde DH. Reconstruction of the hand with wide-awake surgery. *Clin Plast Surg* 2011;**38**(4):761–769
4. Bismil MSK, Bismil QMK, Harding D, Harris P, Lamymen E, Sansby L. Transition to total one-stop wide-awake hand surgery service audit: a retrospective review. *JRSM Short Rep* 2012;**3**(4):23–32
5. Denkler K. Dupuytren's fasciectomies in 60 consecutive digits using lidocaine with epinephrine and no tourniquet. *Plast Reconstr Surg* 2005;**115**(3):802–810
6. Prasetyono TOH. Tourniquet-free hand surgery using the one-per-mil tumescent technique. *Arch Plast Surg* 2013;**40**(2):129–133

7. Prasetyono TOH, Biben JA. One-per-mil tumescent technique for upper extremity surgeries: broadening the indication. *J Hand Surg Am* 2014;**39**(1):3–12.e7
8. Prasetyono TOH, Saputra DKA, Astriana W. One-per-mil tumescent technique for bone and joint surgery in hand. *HAND* 2014. Available at: link.springer.com/article/10.1007/s11552-014-9661-7#page-1. Accessed February 4, 2014
9. Ramirez OM, Galdino G. Does tumescent infiltration have a deleterious effect on undermined skin flaps? *Plast Reconstr Surg* 1999;**104**(7):2269–2272
10. Cleophas RC, Cleophas TJ. Is selective reporting of clinical research unethical as well as unscientific? *Int J Clin Pharmacol Ther* 1999;**37**(1):1–7
11. Ahn J, Pogrel MA. The effects of 2% lidocaine with 1:100,000 epinephrine on pulpal and gingival blood flow. *Oral Surg Oral Med* 1998;**85**(2):197–202
12. Chu WS, Park SH, Ahn DK, Kim SK. Effect of local anesthesia on pulpal blood flow in mechanically stimulated teeth. *J Kor Acad Cons Dent* 2006;**31**(4):257–262
13. Atabey AM, Galdino G, El-Shahat A, Ramirez OM. Effects of tumescent solutions containing lidocaine and epinephrine on skin flap survival in rats. *Ann Plast Surg* 2004;**53**(1):70–72
14. Lalonde DH. "Hole-in-one" local anesthesia for wide-awake carpal tunnel surgery. *Plast Reconstr Surg* 2010;**126**(5):1642–1644
15. Lalonde DH. Wide-awake flexor tendon repair. *Plast Reconstr Surg* 2009;**123**(2):623–625
16. Youha SA, Lalonde DH. Update/review: changing of use of local anesthesia in the hand. *PRS GO* 2014;**2**(5):e150
17. Lalonde DH, Martin A. Tumescent local anesthesia for hand surgery: improved result, cost effectiveness, and wide-awake patient satisfaction. *Arch Plast Surg* 2014;**41**(4):312–316