One-per-mil tumescent technique for bone and joint surgery in hand

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Abstract

Background This study aims to explore the effectiveness of one-per-mil tumescent technique in hand surgery, which involves bone and joint.

Methods This is a case series study on 14 patients with 15 operative fields. One-per-mil solution is formulated by mixing 0.05 mL of 1:1,000 epinephrine and 100 mg lidocaine in 50-mL saline solution. The solution was injected subcutaneously into the operative area until the skin turned pale. The surgery started 7–10 min after the last injection. We classified the operative field clarity into four categories: totally bloodless, minimum bleeding, acceptable bleeding, and bloody operative field. We also recorded the amount of tumescent solution, top-ups needed, length of surgery, type of anesthesia, and intraoperative pain reported by the patients under local anesthesia.

Results Five patients were operated on under local anesthesia while the other ten were under general anesthesia. Eight cases yielded totally bloodless operative fields, while seven were classified as acceptable bleeding. There were no top-ups and conversion of anesthesia needed during surgery.

Conclusions We consider one-per-mil tumescent technique as a promising successor of pneumatic tourniquet in bone and

joint surgery, especially for lengthy procedures on hand and upper extremity.

Keywords Epinephrine · Fractures · Bone · Hand bones · Lidocaine · Tourniquets

Introduction

To visualize anatomical structures, a clear operative field is mandatory. Therefore, bleeding control holds an important role in surgery. To provide good operative field clarity in extremity surgery, pneumatic tourniquet is commonly used [4, 9, 10, 14, 16]. However, non-tourniquet technique using tumescent injection has been increasingly adopted in the practice of hand and upper extremity surgery [5–7, 11, 13]. Epinephrine injection in end-artery organs has been proven to be safe and provides an alternative method for surgeons to obtain a bloodless operative field [3, 4, 9, 10, 12–14, 16]. The safety of epinephrine as a chemical tourniquet in hand and finger surgery has been ratified by some studies [2, 5, 8, 15, 17]. Those studies lead to a broader application of tumescent solution in surgery [1, 5–7, 13]. The use of tumescent solution ranges from soft tissue surgery, congenital defect reconstruction, burn contracture release, and bone surgery [4].

Non-tourniquet technique by anesthetic solution containing epinephrine is a convenient technique for short as well as lengthy procedures and for simple cases as well as meticulous works [5, 11]. Recent reports also show that non-tourniquet technique using one-per-mil tumescent solution provides clear operative fields [4, 11]. This study is intended to elaborate the use of one-per-mil tumescent solution as chemical tourniquet in surgery for bone and joint.

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Materials and Methods

We conducted a case series study, which included cases collected from April 2011 to December 2013. All of the patients underwent non-tourniquet bone surgery in their hand and wrist areas. One-per-mil tumescent solution was chosen over pneumatic tourniquet to provide a bloodless operative field. Prior to the surgery, all subjects provided written informed consent as well as photo and video release consent. 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(5). Informed consent was obtained from all patients for being included in the study.

Fifty milliliters of one-per-mil tumescent solution was formulated by mixing 0.05 mL of 1:1,000 epinephrine and 100 mg lidocaine in saline solution. The solution was injected subcutaneously into the operative area until the skin turned pale, with the maximum lidocaine dose of 7 mg/kg. Injection also targeted the bone deficit by avoiding structures like tendon overlying the bone. The incision was commenced 7–10 min after the last injection.

We recorded the clarity of the operative field, the amount of injected tumescent solution, the need of additional injection, and the length of surgery. We also recorded self-reported intraoperative pain in patients who received local anesthesia by using visual analog scale (VAS), including the timing of the pain. Neither sedation nor pre-emptive analgesia was given to the patients who underwent local anesthesia procedure. Conversion into general or regional anesthesia marked the failure of the one-per-mil tumescent technique.

Derived from prior studies [4, 11], the clarity of the operative field was classified into four categories: totally bloodless, minimum bleeding, acceptable bleeding, and bloody operative field. A totally bloodless operative field indicates an excellent hemostasis. Minimum bleeding is a condition where the operative field is not perfectly clear, but the surgeon does not meet any difficulties differentiating anatomical structures and does not need frequent gauzing. Acceptable bleeding is a condition when the surgeon requires frequent gauzing to visualize anatomical structures. A bloody operative field describes a condition where frequent gauzing cannot control the bleeding and the surgeon needs to apply pneumatic tourniquet. The senior author, who created the classification, was the one who observed these parameters subjectively.

Results

We included 12 male and 2 female patients with 15 operative fields in this study. Table 1 describes patients' demographic, diagnosis, and operative procedure details.

Patients' age ranged from 1 to 30 years old. Five patients were operated on under local anesthesia (case entry nos. 4, 5, 7, 8, and 10), while ten others under general anesthesia. The volume of one-per-mil tumescent solution ranged from 6 to 40 mL, depended on the operative area and the type of surgery.

Intraoperative observation demonstrated acceptable bleeding and totally bloodless operative fields. Eight cases were totally bloodless (case entry nos. 1, 4, 5, 6, 7, 8, 11, and 12) while the rest were classified as acceptable bleeding (Table 1). The length of surgery varied from 50 to 300 min. Surgery under general anesthesia was performed in ten patients, while the other five were under local anesthesia without any conversion. There was no additional tumescent solution or top-ups needed. VAS score at the immediate conclusion of the local anesthesia cases was 0.

Discussion

There is no measurable indicator, which can predict sufficient tumescent solution for each operative area and procedure. Injection of the tumescent solution is considered sufficient when the skin turned pale [11]. Therefore, the amount of solution needed is subjective. The width of operative area and the type of procedure also determine the amount of tumescent solution needed.

There were ten patients operated on under general anesthesia. They consisted of six pediatric patients, two complex patients (ray amputation and macrodactyly reconstruction), and two adult patients with fracture who did not want to undergo surgery under local or regional anesthesia. The five cases under local anesthesia were patients diagnosed with phalanx fractures (Table 1). The longest surgery under local anesthesia lasted for 270 min, yet none of the patients complained about pain (Table 1). This result was obtained using 0.2 % lidocaine, which was a lower concentration than Lalonde's report [5] but still provided effective anesthesia. It shows that the one-per-mil tumescent solution is a proper solution to act as anesthetic agent as well as chemical tourniquet. A previous report on one-per-mil tumescent technique showed only two cases with fractures among 63 patients; the cases were non-union fracture and bone fracture of the hands [13]. This series provides more evidence about the effectiveness of one-per-mil tumescent solution for surgical procedures on hands with bone and joint surgery.

In fracture cases, we injected one-per-mil tumescent solution at the dorsal aspect of the hand. The narrow space between the injection site and the bone led to an exaggerative swelling area when excessive tumescent solution was injected subcutaneously. Thus, the vasoconstriction effect reached the periosteum as well.

Table 1 Patients' demographic, diagnosis, surgical procedure, and intraoperative details

No	Age (years)	Procedure	Volume of tumescent solution (mL)	Duration of surgery (min)	Clarity of operative field
1	16	Bone graft (in non-union fracture)	26	120	Totally bloodless
2	4	Syndactyly release, bone graft (in Apert hand)	8.5	300	Acceptable bleeding
3	4	Syndactyly release, bone graft (in Apert hand)	10.7	300	Acceptable bleeding
4	30	ORIF	9	90	Totally bloodless
5	29	ORIF and flexor repair	21	270	Totally bloodless
6	9	Reduction and wiring	6	110	Totally bloodless
7	30	ORIF and flexor tendon repair	9	50	Totally bloodless
8	16	ORIF and FDP tendon repair	20	132	Totally bloodless
9	23	ORIF	23 (9 for first and 14 for second metacarpal)	120	Acceptable bleeding
10	17	ORIF	15	120	Acceptable bleeding
11	16	Ray amputation (in chronic osteomyelitis)	40	195	Totally bloodless
12	30	ORIF	11	60	Totally bloodless
13	1	Straightening procedure by collateral ligaments lengthening and tightening (in macrodystrophia lipomatosa)	7	120	Acceptable bleeding
14	5	Syndactyly release (in Apert hand)	21	180	Acceptable bleeding
15	2	Syndactyly release (in Apert hand)	23,5	150	Acceptable bleeding

FDP flexor digitorum profundus, ORIF open reduction internal fixation

There were four pediatric cases with Apert hand and a case of 1-year-old boy with acrosyndactyly; both are classified as acceptable bleeding (Table 1). According to the senior author's experience in using one-per-mil tumescent technique, acceptable bleeding was the best operative field clarity that could be obtained in Apert hand and other congenital acrosyndactyly cases [13]. The acceptable bleeding in macrodystrophia lipomatosa case was probably because of the larger tissue involved in even more vascular structures. The bone fracture cases yielded a similar outcome because of the inflammation process due to delayed timing of surgery. Apparently, the timing of surgery for the fracture cases was between 1 and 2 weeks after the injury. However, the bleeding was still controllable by frequent gauzing in those cases. There were no difficulties in differentiating anatomical structures during surgery.

The case with chronic finger osteomyelitis (case entry no. 11) was a meticulous procedure involving bone manipulations. The injection was performed from the top of the triangular design and moved farther proximal to avoid the inflammatory area (Fig. 1). The solution was injected without any effort to puncturing the needle more distally; it means the entry point of injection stayed at the top of the triangular design. Nonetheless, one-per-mil tumescent technique had successfully provided a totally bloodless operative field. A clear visualization had facilitated the management of anatomical structures easily, including the neurovascular bundles (Fig. 1).

Since there were no top-ups needed in any of the cases, including those under local anesthesia, we considered that one-per-mil tumescent technique had provided good operative field clarity as well as adequate pain relief. One-per-mil tumescent technique is also preferable than

Fig. 1 A 16-year-old girl with chronic osteomyelitis on her right middle finger (case entry no. 11). The X-ray shows focal bony lysis and sequestrum in the phalanx and joint (*above, left*). Dorsal view of the hand shows inflammation of the proximal middle finger and the design of the incision for ray amputation (*above, right*). Intraoperative picture shows a bloodless operative field (*below, left*). The neurovascular bundle was well identified (*below, right*)

Fig. 2 A 1-year-old boy with macrodystrophia lipomatosa on his right hand (case entry no. 13). X-ray of the hand shows inclination of the index finger (above, left). The phalangeal bones look larger yet considerably have the same length as the adjacent bones. Volar presentation of the hand shows a gigantic thumb and an ulnar-bent giant index finger (above, right). The zigzag line is the design of the incision during the first stage of surgery. Joint manipulation to straighten the index finger was done by lengthening the ligament on the ulnar side and tightening the ligament on radial side of both PIP and DIP joints (below, left). Presentation of the hand after straightening the bent finger (below, right)

tourniquet in cases of long duration or high complexity. In a 5-h surgery utilizing one-per-mil tumescent solution, the surgeon would need only one session of injection. In contrast, pneumatic tourniquet method may require three times of application with two deflation intervals during the surgery. These numbers would increase when the safe limit of tourniquet inflation is narrowed to 90 min.

In the post-reduction macrodystrophia lipomatosa case (case entry no. 13), the second stage surgery lasted for 120 min with acceptable bleeding. The surgery was considered as successful management for abnormally large structures, which would have bigger chance of bleeding. The correction of clinodactyly to straighten the finger was performed by lengthening and tightening the collateral ligaments of the proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints (Fig. 2).

This study showed that one-per-mil tumescent technique provides a reasonable efficacy, both in regard of surgery duration as well as operative field clarity. We could perform a 270-min surgery on a patient under local anesthesia without top-ups, while in the previous study, the longest surgery duration under local anesthesia was 200 min [13]. Nonetheless, it may not be a reliable benchmark for determining one-per-mil tumescent technique use in surgery for the bone and joint, because the data was obtained from a small series. Besides, our study has some limitations. First, the classification of the operative field clarity is subjective in nature, since there was no independent observer apart from the senior

author himself. Second, we could not estimate the total intra-operative blood loss.

In summary, one-per-mil tumescent solution can be an alternative to pneumatic tourniquet in hand surgery involving the bone and joint. It provides good operative field clarity for the surgeon as well as a pain-free procedure for patients under local anesthesia. However, surgeons using one-per-mil tumescent solution should be cautious in cases with inflammation and Apert hands, since they possess a bigger chance of bleeding.

Conflict of Interest Theddeus O.H. Prasetyono declares that he has no conflict of interest.

Debby K.A. Saputra declares that she has no conflict of interest.

Windi Astriana declares that she has no conflict of interest.

Statement of Human Rights We warrant that all procedures in this study 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(5).

Statement of Informed Consent All subjects provided written informed consent as well as photo and video release consent prior to the procedure.

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