

Tumescent Local Anesthesia for the Surgical Treatment of Burns and Postburn Sequelae in Pediatric Patients

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Background: Tumescent local anesthesia is a technique for regional anesthesia of the skin and the subcutaneous tissue, using infiltration of large volumes of local anesthetic. The advantages of this technique are (1) simplicity, (2) prolonged postoperative analgesia, (3) low incidence of bleeding, and (4) anesthetization of a large area of the body. There are no reports on the use of tumescent local anesthesia in pediatric patients.

Methods: In 30 consecutive pediatric burn patients with American Society of Anesthesiologists physical status class I or II who were 1–120 months old (34 ± 31.6 months), after induction of anesthesia with nitrous oxide–oxygen–sevoflurane, infiltration with 0.05% (14 ml/kg) or 0.1% (7 ml/kg) lidocaine solution was performed. Anesthesia was maintained with patients spontaneously breathing with 1.5% sevoflurane in nitrous oxide–oxygen (50%). The maximum dose of lidocaine used was 7 mg/kg. Postoperative pain was assessed by using the Children's Hospital of Eastern Ontario Pain Scale (for patients aged up to 5 yr) and by using a visual analog scale (for patients older than 5 yr). A comparison with a historic control group not treated with the tumescent local anesthesia technique was performed.

Results: No patients were excluded from the study, and no significant variations in the monitored intraoperative parameters were observed. Five patients had an increase in heart rate and respiratory rate at the beginning of surgery, and of these, two needed a temporary increase in sevoflurane concentration. After the initial incision, no response to painful stimulus was observed. No complications occurred. Six patients required postoperative acetaminophen administration, and 24 patients did not require analgesic treatment.

Conclusions: Tumescent local anesthesia with maximum dose of 7 mg/kg lidocaine seems to be safe and the sole possible effective locoregional anesthesia technique for the surgical treatment of noncontiguous pediatric burns.

TUMESCENT local anesthesia (TLA) is a technique that provides anesthesia of large areas of skin and subcutaneous tissue by means of the direct infiltration of large volumes of a dilute local anesthetic solution into subcutaneous fat. The injection of such large volumes of fluid produces swelling and firmness (tumescent) of the surgical area. TLA was described for the first time in 1987 by Klein for liposuction.¹ Since then, TLA has been widely studied in awake adults for plastic surgery, general surgery, gynecology, and orthopedics. This technique has been shown to be safe in adult patients regarding lidocaine adsorption and toxicity.^{2–7} There are

no reports examining the use of TLA in pediatric patients undergoing surgery for the treatment of burns and postburn sequelae.

The infiltration of the tumescent local solution may be performed manually (syringe alone or syringe with bag and infusion set) or using a mechanical technique with an infusion pump.⁸

The aim of this study was to evaluate the use of the TLA technique in conjunction with general anesthesia for the surgical treatment of burns and postburn sequelae in pediatric patients.

Methods

Thirty unpremedicated pediatric patients with American Society of Anesthesiologists physical status class I or II underwent general anesthesia and TLA for the surgical treatment of acute burns (superficial necrectomy by dermabrasion) or postburn sequelae (escharectomy, skin harvesting, and autologous skin grafting). The patients did not require opioids before surgery. Written informed consent was obtained from each parent after explanation of the study, which was approved by the District Ethics Committee of Meyer Children's Hospital in Florence, Italy.

Patients were excluded if one or more of the following criteria were present: (1) heart disease, (2) actual infection of surgical site (relative criterion), (3) history of local anesthetic allergy, or (4) renal failure.

Induction of anesthesia was performed using a face-mask with 50% nitrous oxide–oxygen–sevoflurane. A laryngeal mask airway, a cuffed oropharyngeal airway, or an endotracheal tube was placed when the patient was sufficiently anesthetized to tolerate airway manipulation. Anesthesia was maintained with patients spontaneously breathing with 1.5% sevoflurane in nitrous oxide–oxygen (50%). This sevoflurane concentration was increased only when heart rate and blood pressure presented an increase of 20% from the baseline. Muscle relaxants were not used. Monitoring included pulse oximetry, electrocardiography, and monitoring of respiratory rate, end-tidal carbon dioxide, blood pressure, and urine output.

The tumescent local solution was prepared on the day of surgery in the operating room, immediately before surgery, and consisted of 0.05% (0.5 mg/ml) or 0.1% (1 mg/ml) lidocaine and 10 mEq/l sodium bicarbonate in lactated Ringer's solution with 1:1,000,000 epinephrine without antiinflammatory additives. The maximum dose of lidocaine was set at 7 mg/kg, corresponding to 7 ml/kg for 0.1% dilution and 14 ml/kg for 0.05% dilu-

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Fig. 1. Tumescent local anesthesia for skin harvesting from thigh in a 2-month-old infant.

tion. The concentration was decided on the basis of the surgical site: the wider the surgical site is, the lower the concentration is and the larger the volume is. Infiltration was performed using a manual technique with a syringe alone (fig. 1), both for harvesting the skin graft and for the burn excision (figs. 2-4). The solutions were warmed in an incubator adjusted at 37°C.

If the infiltration of tumescent local solution produced a *peau d'orange* appearance of the overlying skin, surgery was started after a minimum of 30 min to avoid undermining of skin graft due to the vasoconstrictive property of epinephrine combined with the hydrostatic pressure within a superficial tissue plane.⁹ If the surgical site was in proximity to the fingers, toes, or penis, then a solution without epinephrine was used.

Areas anesthetized included the scalp, anterior chest, posterior chest, neck, face, arms, forearms, hands, thighs, legs, and feet. However, in this study, the burned area never exceeded 20% of the total body surface.

Postoperative pain was assessed by using the Chil-



Fig. 2. Tumescence aspect of the surgical site after infiltration.



Fig. 3. Minor bleeding after skin harvesting.

dren's Hospital of Eastern Ontario Pain Scale for patients aged up to 5 yr and by using a visual analog scale for patients older than 5 yr. Evaluation of pain was performed every hour for the first 6 h and every 3 h for the next 18 h. Acetaminophen, 30 mg/kg by rectal route, was administered if the Children's Hospital of Eastern Ontario Pain Scale score was at 8 or higher and the visual analog scale score was 3 or higher.

The following data were collected: (1) place and area of surgical site; (2) duration of surgery; (3) response to painful surgical stimulus at the beginning of and during surgery, with subsequent need to increase general anesthesia; (4) concentration and volume of tumescent solution infiltrated; (5) postoperative pain assessment by administration of adequate pain score scales; (6) analgesic agent requirements; (7) satisfaction of parents and nurses (a = very satisfactory; b = satisfactory; and c = not satisfactory); and (8) success or failure of grafting.

Therefore, to provide a comparative group, 30 consecutive pediatric burn patients, treated previously, were



Fig. 4. Tumescent local anesthesia in burn site for burn excision and autologous skin graft.

Table 1. Demographic, Surgical, and Monitoring Data

	TLA Group	Historic Control
Number	30	30
Sex (M/F)	17/13	20/10
Age, months	34 ± 31.6 (1–120)	32 ± 29.6 (2.2–96)
Weight, kg	13.4 ± 6.3 (3.1–30)	13.7 ± 6.4 (3.6–35)
Duration of surgery, min	36.4 ± 27.5 (10–90)	42.1 ± 30.4 (12–94)
Time between TLA and beginning of surgery, min	15.7 ± 6.1 (10–34)	
Area of surgical site, cm ²	179 ± 165.2 (21–758)	144 ± 94.7 (30–550)
Volume of tumescent local solution, ml	101.5 ± 90.9 (20–480)	
SpO ₂ , %	96–100	96–100
End-tidal CO ₂ , mmHg	38.7 ± 4.3 (31–44)	36.5 ± 2.8 (32–42)
Morphine consumption, mg · kg ⁻¹ · 24 h ⁻¹	0	13.2 ± 3.6 (3.5–42)
Ketamine consumption, mg · kg ⁻¹ · 24 h ⁻¹	0	86.4 ± 12.7 (34.6–184.3)

Ranges are given in parentheses.

CO₂ = carbon dioxide; SpO₂ = oxygen saturation; TLA = tumescent local anesthesia.

retrospectively analyzed (historic control). These patients underwent general anesthesia by the same technique as the TLA group; fentanyl was administered intraoperatively by intravenous bolus, and postoperative analgesia was performed with infusion of morphine, ketamine, and/or rectal acetaminophen. Data are reported as mean ± SD and range.

Results

Demographic, surgical, and anesthetic details are reported in table 1. No significant differences were found between the groups.

In the TLA group, five patients (16.7%) had an increase in heart rate and respiratory rate at the beginning of surgery; of these, two patients needed a transient increase in sevoflurane concentration. No patient exhibited movement in response to surgical incision or during the operation. After the initial incision, no clinically important changes in intraoperative heart rate or blood pressure were observed. Blood transfusion was never necessary.

The average volume of tumescent anesthetic solution was 101.9 ± 90.9 ml (range, 20–480 ml). The solution concentration used was 0.05% in 13 cases and 0.1% in 17 cases. The average area of the surgical site was 179 ± 165.2 cm² (range, 21–758 cm²).

No complications occurred during the postoperative period; in particular, no hematomas developed, and no failure of grafting was observed.

In the TLA group, all but six patients (20%) were painfree in the postoperative period; no analgesic regimen was necessary throughout the observation period (24 h) because the analgesic cutoff of the pain scales was never reached. Six patients required postoperative analgesic treatment; of these, one patient required three, one patient required two, and three patients required one dose of acetaminophen. In terms of postoperative analgesia, the TLA technique was so striking that we did not

consider it ethical to perform a prospective controlled study. Therefore, we compared the TLA group with the historic control.

Parent evaluations of their children's comfort were very satisfactory in 24 cases and satisfactory in 6 cases; nurses were very satisfied in 23 cases and satisfied in 7 cases.

In the historic control group, postoperative analgesia was achieved with intravenous infusion of morphine (30–50 μg · kg⁻¹ · h⁻¹) or ketamine (4 μg · kg⁻¹ · min⁻¹) and, if the Children's Hospital of Eastern Ontario Pain Scale score was 8 or greater or the visual analog scale score was 3 or higher, rectal acetaminophen (30 mg/kg). Comparison data between the two groups are reported in table 1.

Discussion

This study seems to confirm in children the specific advantages of TLA, which have already been shown for adults (table 2). Unlike other regional techniques, the use of large volumes of tumescent solution makes it possible to anesthetize wide superficial areas of the body that may not be contiguous, as is often the case in burn patients.

The use of the TLA technique results in lower blood loss because of the presence of vasoconstrictor in the solution, and the separation of tissue planes by the injectate allows the surgeon to have an improved plane of

Table 2. Purported Advantages of Tumescent Local Anesthesia²³

Anesthesia of wide areas of the body
Simple and safe method
Hydrodissection as a surgical tool
Low bleeding
Improved in hematoma resorption
Long duration of the effect of local anesthetic with subsequent prolonged postoperative analgesia
Antibacterial effect

dissection.¹ The concentration and volume of the solution may differ on the basis of the size of the surgical site: the wider the surgical site is, the lower the concentration is and the larger the volume is. TLA has been reported to produce analgesia for a duration of up to 18 h.³

When TLA is used for liposuction, using a 0.05–0.4% lidocaine solution, peak blood and plasma concentrations occur 4–14 h after infiltration.^{4,5,10} With few exceptions,⁷ peak plasma concentrations of lidocaine with TLA remain below 5 µg/ml, which is considered to be the toxic threshold of lidocaine in adults, even though one must remember that during liposuction, most of the dilute lidocaine solution is removed by the suction.

The rate of lidocaine adsorption is related not only to concentration and epinephrine but also to low perfusion of skin and subcutaneous tissue. The speed of infiltration does not seem to determine the rate of lidocaine adsorption.¹¹ The maximum safe dose for TLA of 55 mg/kg lidocaine, recommended by the American Society of Dermatologic Surgery in 1997,¹² seems to be safe for most patients undergoing liposuction.¹³ However, it must be stressed that (1) this dose is in reference to awake adult patients, who can therefore recall, if they are not heavily sedated, every initial toxic symptom; and (2) the technique of tumescent liposuction can be fatal, as demonstrated by five deaths in plastic surgeons' offices, which may have been related to local anesthetic toxicity.⁷ In our study, TLA was performed after induction of general anesthesia and with no removal of the injected solution by suction; for these reasons, we did not exceed the maximum dose of lidocaine with 10 mg/kg epinephrine recommended for standard local anesthesia in children.¹⁴

Tumescent local anesthesia solution has been reported to have antibacterial effects¹⁵ due to lidocaine's bacteriostatic properties, which are enhanced by the addition of sodium bicarbonate¹⁶ and the washout effect of the solution commonly used in TLA.¹⁰

Although performed in conjunction with general anesthesia, the safety of the pediatric TLA technique seems to be warranted by the following factors: (1) the dose of lidocaine not exceeding 10 mg/kg with epinephrine, the recommended maximum dosage for regional blocks in children,¹⁴ so becoming a low-dosage TLA; (2) the high dilution of local anesthetic solution with subsequent long-duration absorption; (3) the absence of premedication with benzodiazepines, such as midazolam, so avoiding the use of two substrates on the same enzyme, CYP3A4, with a lower risk of reaching toxic plasma concentrations¹⁷; (4) the warming up of the solution with decreased risk of inducing hypothermia⁴; and (5) fluid administration limited to maintenance fluid with minimal risk of fluid overload.¹⁸

Because large volumes of tumescent solution may be infiltrated, it is advisable to warm the solution to physi-

ologic body temperature to decrease the potential risk of hypothermia.⁴

The vasoconstrictive effect of epinephrine to the tumescent solution has three consequences: (1) limitation of bleeding (fig. 3), which is especially important when tissue sampling is performed from the scalp; (2) contribution to prolonging the anesthetic effects of lidocaine; and (3) slowing and delay of lidocaine absorption.

One of the most impressive aspects of TLA is postoperative analgesia, characterized by the long duration, up to 18 h,³ and the low requirement for analgesics. Burn pain has some degree of neuropathic pain, and TLA could relieve this discomfort like an intravenous local anesthetic.¹⁹ The results of this study seem to confirm such data, and for this reason, it did not seem ethical to perform a prospective controlled study. It was considered interesting to perform a comparison with a historic group of pediatric burn patients not treated with TLA. TLA results in extensive infiltration of surgical wounds, a well-known and widely used method of preemptive analgesia for the treatment of postoperative pain. To explain the long duration of the effect of TLA, Raymond *et al.*²⁰ demonstrated that the degree of conduction blockade in single nerve fibers exposed to a constant concentration of local anesthetic increases with the length of the exposed nerve segment. In TLA, larger areas than in conventional methods of local regional anesthesia are exposed to large doses of local anesthetic; this mechanism could represent the basis of long-lasting blockade of nerve conduction and therefore of prolonged analgesia. If this mechanism really explains the prolonged postoperative analgesia, the use of either short- (*i.e.*, lidocaine) or long-lasting (*i.e.*, ropivacaine) local anesthetics should not involve any difference in terms of the duration of the effect. However, on the contrary, Breuninger *et al.*²¹ used ropivacaine as an anesthetic agent for tumescent anesthesia, concluding that ropivacaine lasted more than twice as long as lidocaine.

Disadvantages of TLA are that (1) TLA fluid may go into the surgical site, (2) performing infiltration is time-consuming, and (3) it may be associated with more difficult identification of bleeding sources.^{22,23}

It must be stressed that in our study, the burned area was less than 20%. In larger burns requiring larger doses of lidocaine, this method might be dangerous. Further pharmacokinetic studies and information regarding absorption from large inflamed sites in burned children are necessary.

We are also aware that the study has the methodologic problem of not being a prospective controlled randomized study; therefore, it is open to many forms of bias. This study represents a simple series of observations regarding the use of TLA in pediatric patients leading to the following final conclusions: (1) low-dosage TLA seems to be a safe and the sole possible local regional anesthesia technique for the surgical treatment of non-

contiguous burns in pediatric patients, (2) this technique is easy to perform, (3) the success rate is very high, and (4) postoperative analgesia seems to be prolonged.

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