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ORIGINAL ARTICLE

Factors determining the doses of local anesthetic agents in unilateral inguinal hernia repair

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Abstract
Background Today, local anesthesia is used in specialized hernia clinics in most cases. The technique for establishing local anesthesia for inguinal surgery may differ among surgeons. Few articles to date have mentioned the exact doses of local agents. This prospective study aimed to research the doses of local anesthetic agents needed in practice and determine the patient-related and other factors which affected those doses.
Methods Three hundred consecutive patients who underwent an elective unilateral inguinal hernia repair were planned to be included in the study. Lidocaine as a short-acting, medium-lasting agent and bupivacaine 0.5% as a long-acting agent were chosen. Gender, age, body mass index (BMI), side of hernia (right/left), concomitant disease, history of hernia (primary/recurrent), type of hernia (indirect/direct), Gilbert class of hernia (1–6), size of hernia (small or medium/large or massive), hernia sac content (omentum/intestine), time shift (8 am to 4 pm/later than 4 pm), duration of operation, and institutional experience (first 150 cases vs. latter 150 cases) were recorded.
Results There were 277 male and 23 female patients. The mean age was 49.73 years (range 16–83; median 50.00). The mean volume of total anesthetic agents (lidocaine + bupivacaine) was 19.79 ml (range 5.5–40; median 19.5). The mean volumes separately were 101.79 mg for lidocaine (range 30–200; median 100) and 48.12 mg for bupivacaine (range 12.5–110; median 50). The patients were discharged after a median time of 2 h postoperatively. Univariate analysis for the total dose of the two agents showed that younger age ($\leq$60 vs. $\geq$61 years), larger size of hernia, longer duration of operation ($\geq$61 vs. $\leq$60 min), recurrent hernia, hernia sac content (omentum > intestine), and higher BMI ($\geq$25.1 vs. $\leq$25.0) were significant parameters. On the other hand, BMI, recurrent hernia, size of hernia, and omentum in the hernia sac were factors that significantly affected the mean lidocaine dose. Higher BMI and recurrent hernia also caused a higher need for bupivacaine. In addition, significantly lower doses of bupivacaine was used in older patients. The significant independent parameters in the multivariate analysis were duration of operation, sac content, and BMI for lidocaine dose, whereas the duration of operation and sac content were determinative for the sum volume of the two agents. None of the recorded parameters were found to be significant for bupivacaine dose in the logistic regression.
Conclusions This prospective study showed, again, the feasibility of local anesthesia in elective inguinal hernia repair in all patient groups with different characteristics. The mean and maximum doses of local anesthetic agents were well within safety limits, even in recurrent and large hernias. Younger age, large hernias, recurrent hernias, omental mass in the hernia sac, high BMI, and duration of operation might be the factors affecting local anesthetic doses. The significant independent parameters in the multivariate analysis were duration of operation, sac content, and BMI for lidocaine dose, whereas the duration of operation and sac content were determinative for the sum volume of lidocaine and bupivacaine.

Keywords Hernia · Inguinal hernia · Local anesthesia · Lidocaine · Bupivacaine · Lichtenstein · Mesh · Recurrent hernia · Body mass index

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Introduction

The history of local anesthesia for groin hernia repair is very extensive. It was first introduced at the very beginning of the last century [1]. Then, the method was popularized by Shouldice Hospital and the Lichtenstein Hernia Institute during the second half of the same century [2, 3]. Today, local anesthesia is used in specialized hernia clinics in most cases [4–6], while its use is still not a common practice in district general hospitals and teaching hospitals, in spite of its proven advantages [7, 8].

The technique for establishing local anesthesia for inguinal surgery may differ among surgeons. Mainly two techniques, neural blockade and tissue infiltration, are in use; however, the choice of local anesthetic agents and their doses may show variability.

There are numerous reports on the feasibility of local anesthesia for inguinal hernia repair. The names and concentrations of local agents have usually been given by the authors, but few articles mention the exact doses of local agents. As a specific hernia center using local anesthesia routinely, we aimed to report the doses of local anesthetic agents and determine the patient-related and other factors affecting the doses needed.

Methods

It was planned to enroll 300 consecutive patients who underwent an elective unilateral inguinal hernia repair with a prospective protocol. All patients read and signed a written informed consent before the operation. The local anesthetic procedure was explained to the patients in detail by the operating surgeon. Bilateral hernias, emergency cases, and patients who required general anesthesia were excluded. The following parameters were meticulously recorded: gender, age, body mass index (BMI), side of hernia (right/left), concomitant diseases, history of hernia (primary/recurrent), type of hernia (indirect/direct), Gilbert class of hernia (1–6), size of hernia (small or medium/large or massive), hernia sac content (omentum/intestine), time shift (8 am to 4 pm/later than 4 pm), duration of operation, institutional experience (first 150 cases vs. latter 150 cases), level of intravenous sedation (light/mild).

Local anesthesia was employed as previously described by the Lichtenstein Hernia Institute [3]. A local infiltration technique was used without any nerve blockade. Lidocaine as a short-acting, medium-lasting agent (Jetocaine simplex ampules 40 mg/2 ml, Adeka) and bupivacaine 0.5% as a long-acting agent (Marcaine 0.5% flacon 20 ml, AstraZeneca) were chosen for all cases. No adrenaline was added. Intravenous sedation was set with midazolam (0.07 mg/kg) and fentanyl (0.70 μg/kg).

Before commencing the local anesthesia and sedation, noninvasive blood pressure monitoring, electrocardiography, and oxygen saturation monitoring with a pulse oximeter were set. A total dose of 10 ampules of lidocaine and 0.5% flacon of bupivacaine were first prepared in separate places. These volumes of agents were diluted with equivalent volumes of saline (1/1 volume). All of the operations were done by the same surgeon (HK) with the same second surgeon's (IO) assistance. The incision was marked with a permanent pen. The first injection of lidocaine was done subdermally and then intradermally by the guidance of skin marking; 5–8 ml of lidocaine was injected at this level. Lidocaine has only a 1–2-min onset time and its use at this level gives the surgeon a quick start to surgery with skin incision. Subcutaneous tissues were infiltrated step-by-step using lidocaine and bupivacaine. A standard dose of 8 ml of bupivacaine was given under the external aponeurosis with a 21 G needle. This is the main and long-acting anesthetic infiltration of the inguinal floor. After opening the external aponeurosis, a 1–2-ml dose of bupivacaine was injected into the mesentery of the spermatic cord. This injection and the other additional local anesthetic injections were administered gently with an insulin needle in small portions into the hernia sac and the pubic tubercle. Extra local agents were also given in 1-ml portions when needed. The main reason for the extra doses was the dissection of the peritoneal sac, which may be quite painful sometimes. Lidocaine was the preferred agent at this point of the operation because of its rapid onset. The total doses of two separate agents in milliliters were strictly recorded by the scrub nurse. These figures were converted to doses in milligrams later. All of the repairs were completed with the Lichtenstein technique using 8 × 15-cm standard polypropylene meshes.

The relation between the independent parameters and the local anesthetic agents' doses was statistically determined; SPSS for Windows version 11.0 was used. Student's *t*-test and the Mann–Whitney *U*-test were used for the univariate analysis. The Kruskal–Wallis test was employed when the means of three or more groups were compared. Multivariate analysis was done using the logistic regression test.

Results

Only one single patient requested general anesthesia in advance and was excluded from the study. No conversion toward general anesthesia because of patient intolerance or agent-related intraoperative complication was needed in any of the cases.

There were 277 male and 23 female patients. The mean age was 49.73 years (range 16–83; median 50.00). The mean volume of total anesthetic agents (lidocaine + bupivacaine)

was 19.79 ml (range 5.5–40; median 19.5). The mean separate doses in milligram were 101.79 mg for lidocaine (range 30–200; median 100) and 48.12 mg for bupivacaine (range 12.5–110; median 50).

The patients were discharged after a median time of 2 h postoperatively. There were only two re-admissions due to dizziness following an uneventful discharge. One more patient informed the center by phone about his admission and a short duration of hospitalization at a district hospital on their way home. Five patients stayed overnight in the center because of social reasons (came from another town, no close relatives to help, etc.).

The duration of operation was significantly longer for recurrent hernias compared to primary cases (90.6 vs. 61.4 min; $P = 0.001$). Higher BMI (≥25.1) also caused longer operations (72.3 vs. 60.1 min; $P = 0.001$). The difference between indirect and direct hernias regarding the same parameter did not reach the level of significance (69.3 vs. 63.6 min; $P = 0.056$). The duration of operation was also raised significantly by the size of hernia (small: 58.3, medium: 61.4, large: 74.7, massive: 101.4 min; $P = 0.001$).

Univariate analysis for the total dose of the two agents showed younger age (≤60), larger size of hernia, longer duration of operation (≥61), recurrent hernia, hernia sac content (omentum), and higher BMI (≥25.1) to be significant parameters (Table 1). On the other hand, BMI, recurrent hernia, size of hernia, and omentum in the hernia sac were factors that significantly affected the mean lidocaine dose. Higher BMI and recurrent hernia also caused a higher need for bupivacaine. In addition, significantly lower doses of bupivacaine was used in older patients.

The significant independent parameters in the multivariate analysis were duration of operation, sac content, and BMI for lidocaine dose, whereas the duration of operation and sac content were determinative for the sum volume of the two agents. None of the recorded parameters were found to be significant for bupivacaine dose in the logistic regression.

Table 1 Univariate analysis for mean doses of lidocaine and bupivacaine in milligram, and mean sum undiluted volume of the two agents in milliliter

	Lidocaine dose (mg)	Bupivacaine dose (mg)	Total dose (ml)
Gender			
Male	102.18	47.97	19.81
Female	96.90	50.00	19.59
P	*0.252*	*0.658*	*0.811*
Age (years)			
≤60	101.37	49.78	20.12
≥61	102.94	43.72	18.93
P	*0.810*	***0.001***	***0.048***
Age group			
<40	101.88	50.00	20.29
40–60	101.25	49.62	20.02
≥61	102.56	43.72	18.89
P	*0.924*	*0.034*	*0.366*
BMI			
≤25.0	93.53	43.88	18.12
≥25.1	107.88	50.34	20.85
P	***0.001***	***0.001***	***0.001***
Side			
Right	101.25	48.37	19.78
Left	102.58	47.75	19.80
P	*0.587*	*0.740*	*0.975*
Coexisting disease			
−	101.32	48.30	19.81
+	102.73	47.75	19.74
P	*0.806*	*0.778*	*0.907*
History			
Primary	100.09	47.22	19.44
Recurrent	117.86	56.61	23.18
P	***0.008***	***0.003***	***0.003***
Type			
Direct	99.95	49.82	19.94
Indirect	103.89	47.64	19.90
P	*0.438*	*0.273*	*0.955*
Gilbert class			
1	78.13	45.63	16.94
2	97.35	44.79	18.67
3	123.20	52.45	22.81
4	100.51	48.90	19.82
5	104.41	50.59	20.38
6	101.00	43.50	18.90
P	***0.001***	***0.038***	***0.001***
Size			
Small	89.27	47.19	18.26
Medium	98.00	47.54	19.25
Large	110.63	48.71	20.94
Massive	125.29	53.68	23.15

Discussion

Although local anesthesia provides maximum comfort for the patients in selected institutions, its use may cause discomfort to the patient and surgeon when the application is not performed properly. A satisfactory local anesthesia for inguinal hernia repair requires both an appropriate technique and satisfactory doses at the same time. It may not be possible to set a perfect local anesthesia if the given dose is not enough. The local anesthesia technique has a learning curve requiring specific training. Inexperience with local anesthetic technique can cause both discomfort to patients and an increased recurrence rate [9].

Table 1 continued

	Lidocaine dose (mg)	Bupivacaine dose (mg)	Total dose (ml)
P	***0.001***	*0.401*	***0.001***
Size group			
Small–medium	95.44	47.46	18.96
Large–massive	113.73	49.53	21.38
P	***0.001***	*0.293*	***0.001***
Sac content			
Omentum	127.35	50.81	22.84
Intestine	98.02	46.25	19.03
P	***0.001***	*0.124*	***0.001***
Shift			
Day	107.06	48.44	20.37
Evening	98.81	47.99	19.57
P	*0.154*	*0.831*	*0.249*
Duration (min)			
≤60	87.69	43.01	17.27
≥61	113.60	52.09	21.84
P	***0.001***	***0.001***	***0.001***
Experience			
# 1–150	101.56	49.48	20.02
# 151–300	102.03	46.79	19.57
P	*0.900*	*0.145*	*0.465*
Sedation level			
Light	100.16	46.76	19.64
Mild	113.54	48.45	21.31
P	*0.142*	*0.784*	*0.260*

Our facility is equal to the American Association for Accreditation of Ambulatory Surgery Facilities Level C Center (patients can receive general anesthesia, if needed or requested, by means of endotracheal tube, laryngeal mask, or inhalation anesthesia). Only one patient requested general anesthesia preoperatively. No need for conversion to general anesthesia was recorded during the study period. Tolerance to the local anesthesia technique was very good. No significant intraoperative deterioration was recorded. Only five patients (1.67%) required an overnight stay because of social reasons. Sanjay and Woodward similarly reported that most of the overnight stays were social admission [10]. Their re-admission rate was 2.7% after local anesthesia. The re-admission rate was also as low as 1% in the present study.

Like every drug administered to the human body, local anesthetic agents have their own dose limitations. The maximum doses of local anesthetics were well-documented. However, there is still a global concern about the safety of large doses of local agents. There is a textbook reference that lidocaine, without epinephrine, can be administered as up to a total dose of 200–300 mg with no harm [11, 12]. The U.S. Food and Drug Administration recommend doses of lidocaine is as high as 7 mg/kg currently [13]. It has a very rapid onset of action within just 2–4 min and is a preferred agent for skin incision. Because of bupivacaine's slow onset of action, which can be observed within 5–8 min at the earliest [14], we first use that agent for subcutaneous infiltration and later for a 6–8-ml injection beneath the external aponeurosis. Bupivacaine is much more potent than lidocaine regarding the duration of anesthetic effect. It can retain its anesthetic action for 4–6 h, whereas lidocaine has 1–2 h of lasting action [12, 15]. Bupivacaine is generally used in a total dose of 150–200 mg or 2 mg/kg, while 4 mg/kg is the current recommended dose [4]. Kastrissios et al. [16] demonstrated that the peak plasma level of bupivacaine was far lower than its cardiovascular and central nervous system toxicity levels after using 20 ml of 0.5% solution for wound infiltration after inguinal hernia repair. Their dose was almost two-fold the volume that is used in the present study. The peak level was observed at between the 15th min and the 2nd h after bolus administration. Karatassas et al. reported that a similar pattern is true for lidocaine. They observed that the peak lidocaine concentration was still much lower than the toxic level, despite the fact that a 7-mg/kg infiltration dose was used [17]. These observations make a discharge 2 h after the completion of the operation, as done in our institution, completely safe.

The use of a mixture of local anesthetics has become popular in recent years, despite some advocates that there are no significant advantages to the use of mixtures [12]. However, as we have explained before, the differences between two agents in respect of action time and duration provide lidocaine and bupivacaine with different advantages compared to using them separately. Diluting the local agents with saline creates increased volume solutions with lower concentrations. This may avoid complications and provides better analgesic cover in generously infiltrated areas [18, 19].

Bupivacaine is generally a safe agent for local infiltration, as explained above. Nevertheless, its use may pose some risks when the patient has concomitant cardiovascular or central nervous system disorders. Respiratory depression can be developed or bradycardia can be observed if the patient has been using beta-blockers. Bradycardia was a problem in some cases in the present series indeed, but this was related to peritoneal tension during sac dissection. Some patients needed atropine administration and responded in a minute, while others became normal with just a little more jetocaine infiltration of the local peritoneum. In fact, bupivacaine was cautiously used in this group of patients according to the anesthetist's request in the present series. This might create a bias for the study. However, the final mean dose of bupivacaine in this group of patients was not found to be significantly lower.

It has been our observation and other hernia specialists' informal statements that older patients may need fewer local agents because of their less muscular body structure and free-of-stress on-table situation. The present study confirmed this assumption by showing that the older the patient, the lower the bupivacaine and total local anesthetic doses needed. Nevertheless, the effect of age on bupivacaine dose disappeared in the logistic regression test. Our patients older than 60 years of age needed only a mean of 43.72 mg of bupivacaine. The age threshold was 65 years in Nienhuijs et al.'s study on hernia repair with local anesthesia in the elderly [20]. They used a total of approximately 30 ml as a mixture of 0.5% lidocaine and 0.125% bupivacaine with no complications.

Although the doses of local agents are given in 'mg/kg,' their preparations are commonly based on a 70-kg person. This approach may cause an inefficient local anesthetic dose for overweight patients. However, Reid et al. recently reported that the mean local agent volumes of normal weight and overweight/obese (BMI $\geq$ 25) patients who underwent inguinal hernia repair are not significantly different, while the same level of patient satisfaction was provided [21]. In contrast, the present study has demonstrated significantly different local anesthetic doses between these two groups of patients regarding lidocaine and bupivacaine doses. Obese patients obviously have larger volumes of subcutaneous tissue and a larger area of the inguinal floor to infiltrate for a comfortable procedure. It is the similar findings of the two series that the required doses even for obese patients stay within recommended safety margins in inguinal hernia repairs. We consider this is as good evidence for using local anesthesia in this group of patients as well, despite some studies having excluded patients over 100 kg [22].

Recurrent inguinal hernias, which have a higher surgical failure rate and require more surgical experience in comparison with primary hernias, create a problematic group for surgeons. Patients with a recurrent hernia needed higher local agent doses in the present series in the univariate analysis. The mean bupivacaine dose was recorded as 56.61 mg for recurrent hernias, with a mean of 117.86 mg of lidocaine. Callesen et al. reported an amount of 50 ml of 0.25% bupivacaine solution which was equal to 125 mg of bupivacaine [23]. Unfortunately, they did not discuss this particular dose in detail. The effect of recurrent hernias on local agents' doses disappeared in the multivariate test in our study. This was also the case for the size of hernias, while high BMI and longer operation still retained the importance.

An inguinal hernia operation under general anesthesia generally reduced the sac content after the induction of anesthesia, even in some cases with incarceration. However, sac content can remain out of the abdominal cavity in a great portion of the cases when the operation is done with local anesthesia and the related muscles are not relaxed. Intestinal loops were seen in 42% and omentum in 12% of the cases in our series when the hernia sac was opened. The existence of omentum in the hernia sac was found to be a significant factor for lidocaine dose needed in the multivariate analysis. This was probably due to the fact that omentum usually created a mass resistant to easy reduction in a conscious patient contrary to intestinal loops. In the meantime, peritoneal manipulation caused bradycardia and, as the faster and safer agent, lidocaine was the recommended agent by the anaesthetist in this situation to make the patient comfortable and free of pain. For this reason, omentum in the hernia sac as an independent factor affected lidocaine dose but not bupivacaine dose.

This prospective study showed again the feasibility of local anesthesia in elective inguinal hernia repair in all patient groups with different characteristics. The mean and maximum doses of local anesthetic agents were well within safety limits, even in recurrent and large hernias. Younger age, large hernias, recurrent hernias, omental mass in hernia sac, high BMI, and duration of operation were the factors affecting the sum volume of the two agents. Higher lidocaine doses were needed in patients with higher BMI, recurrent hernia, and omentum in the hernia sac. Higher BMI and recurrent hernia also caused a higher need for bupivacaine. In addition, older patients required significantly lower bupivacaine doses. The significant independent parameters in the multivariate analysis were duration of operation, sac content, and BMI for lidocaine dose, whereas the duration of operation and sac content were determinative for the sum volume of the two agents.

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