ORIGINAL CONTRIBUTION

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Hydrodissection for subperichondrial septoplasty - an experimental anatomical study*

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SUMMARY

Objectives: *The effect of hydrostatic infiltrations for subperichondrial dissection is controversial. Classical textbooks promote it as the "key step in elevating the flaps" or consider its practicability "a mere fable". Moreover, case reports describe fatal side effects. Up to now, experimental tests are missing.*

Design: *Experimental study.*

Materials and Methods: *Three surgeons simulated subperichondrial hydrodissection with 20 mineral salt fixed human cadaver heads. One ml lidocaine 5% with 1:10^5 adrenaline and India ink was infiltrated. Each septum was examined histologically using serial 3 µm sections in 150 µm intervals. Tissue cleavage containing the ink deposits with minimal distance to the proposed subperichondrial zone, intravasal spread and tissue deposition were analyzed.*

Results: *Every injection produced a physical dissection (n = 20). However, dissected planes were localized mostly in the supra-perichondrial connective tissue (n = 8) or within the perichondrium (n = 4). Only five cases showed the propagated correct dissection in a subperichondrial zone. Three anomalous septa were excluded from quantitative analysis. Infiltrated matter did not only accumulate within the dissection plane but also penetrated the surrounding vessels of the septal intumescentia (n = 8).*

Conclusion: *Hydrostatic infiltrations represent an unreliable surgical technique for dissection of an anatomical correct subperichondrial plane but can be useful for anesthesia and hemostasis, however, using high pressure and high volume infiltrations might foster serious side effects.*

Key words: subperichondrial septoplasty, hydrostatic dissection, Thiel fixation

INTRODUCTION

In septoplasty, infiltration of the septum is propagated as serving three main purposes: vasoconstriction for hemostasis, anesthesia and potential "hydrostatic dissection" in a surgical subperichondrial plain, facilitating further identification and dissection of the septal cartilage. Numerous classic textbooks advocate hydrostatic subperichondrial dissection [1-3]. Some surgeons even consider the first injection "as the key step in elevating the flaps, as the injection itself must occur in the correct plane with high pressure to elevate the perichondrium" [4]. However, the utility of this technique has been questioned on theoretical grounds [5,6], or even rejected as a mere "fable of hydrodissection" [7]. Moreover, many authors had to report on rare but devastating complications, which they related to septal infiltrations with local anesthetics and vasoactive substances resulting in blindness or severe cardiovascular events [6,8-13].

Despite this controversy and associated risks, experimental testing of the validity of hydrostatic dissection is still lacking. This histological study investigates whether tissue clefts can be identified by hydrodissection, whether those clefts are reliably located in the propagated subperichondrial zone and where the infiltrated material additionally spreads out.

MATERIALS AND METHODS

Ethical considerations

The study was performed according to the ethical guidelines of the Swiss Academy of Medical Sciences on individuals who had provided written consent to dedicate their body to medical research and educational training purposes for doctors and medical students at the University of Bern, Switzerland [14].

Septoplasty

Three rhinosurgeons with a median of 4 years experience in septoplasty (range: 3-10) (PD, GM, MC) performed the initial step of subperichondrial septoplasty by hydrostatic dissection. Septal infiltration was uniformly performed in contact with the septal cartilage and 1.5 cm distal to the nasal spine using a

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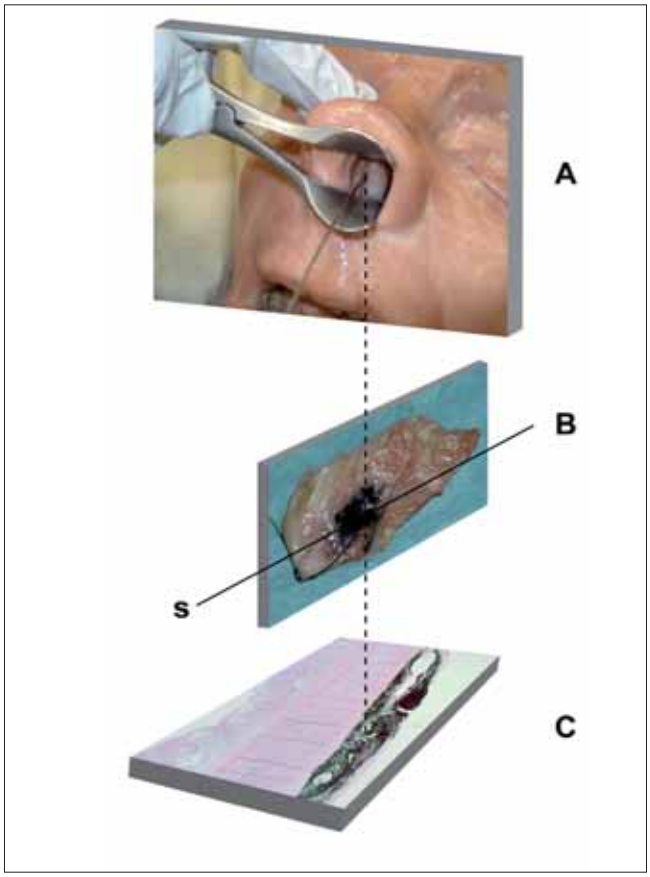

Figure 1. (A) Infiltration of marker fluid (black India ink) with hydrostatic dissection. (B) Septal specimen with section (s) for analysis of the ink-marked dissected zone. (C) Histologic tissue section of 3 μm thickness transversal through the Thiel fixed septum, hematoxylin-eosin staining, at 2.5 x magnification. Note: the dissected plane and tissue spread of the India ink.

speculum, a syringe and a 25-gauge (PD) or 27-gauge (GM, MC) needle (Figure 1A). Clinically used infiltration solution (lidocaine 5% and 1:10^5 adrenalin) with 1:10 India ink (Drawing Ink black, Art. R 591217 Rothring®, Germany) was applied. Single puncture and injection of 1 ml volume with high pressure regularly produced a localized swelling in the submucosal tissue planes in an area of 1.5 to 2 cm^2, potentially preparing the surgical subperichondrial dissection plane (Figure 1B).

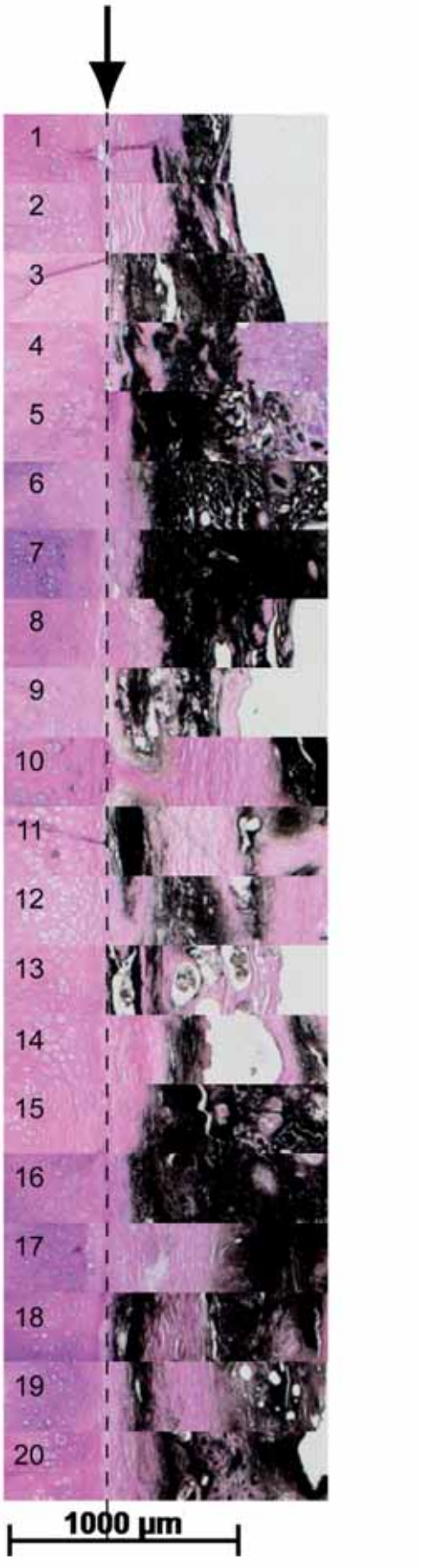

Figure 2. Histological synopsis: Each stripe shows the most representative sample of the dissected plane in one of the 20 septa after serial sectioning. Hematoxylin-eosin staining of formalin-fixed, paraffin-embedded 3 μm tissue sections. Anomalous specimens: septum 2 (old perforation), 8 (revision septoplasty) and 16 (pre-existing septal fracture) were excluded from statistical analysis.
Note: The distance between the dissection plane containing the black ink and the subperichondrial target zone (arrow and dashed line) is random.

All cadaver heads were preserved with a standard protocol of Thiel mineral salt fixation [15] for up to one year before our experiments could be performed. Experiments were performed on 20 heads (9 female) with a mean age of 80.7 years (range: 50-94) and of 19 Caucasians and 1 African-American. One cadaver septum showed a septal perforation, one a consolidated multifragmented septal fracture and one had already undergone a septoplasty.

Nasal septa were infiltrated unilaterally with the marker substance (Figure 1A) and the contralateral side served as a control for comparison of the effects of infiltration. The area of the quadrangular and perpendicular septal plate was excised in one piece with septum scissors and the anterior septal edge was marked with non-absorbable suture (Prolene® 5-0).
Each septal specimen was cut in a transverse plane horizontally through the center of the infiltration (Figure 1B). For hematoxylin eosin (HE) staining, the specimens were additionaly fixed in 4% formalin for 24 hours, dehydrated in ethanol, embedded in paraffin blocks for 3 μm sectioning. Of the 3 mm central zone of the infiltrated septal area, serial tissue sections of 3 μm thickness, each separated by 150 μm were prepared. Sections were examined at 2.5x and 5x magnification (Figure 1C).

According to previous anatomical studies [16,17], the stratification of the perichondrium in nasal septal cartilage must be defined by zones without clear-cut borders as opposed to cartilage from other sites of the human body (e.g. earlobe, trachea). The subperichondrial zone was defined as the area tangential to the last oval shaped chondrocyte and the dense fibrous bands of the perichondrium. The zone of the perichondrium was defined as the 200 to 300 μm broad, homogenous band of dense collagen tissue beneath the supraperichondrial layers of contiguous connective tissue.

In 17 cases maximal tissue cleavage created by tissue clefts containing the black ink deposits were documented photographically with a μm scale excluding the three septa with anomalies (pre-existing perforation, fracture or operation) from further qualitative analysis. Of all the serial sections investigated, the section with the greatest minimal distance of black cleavage zone in relation to the subperichondrial zone was chosen for analysis. The minimal distance between the tissue plane dissected by the infiltration procedure and the subperichondrial target zone was measured in μm for each septum independently by three investigators (YB, PD, GM).

Statistical analysis
Statistical analyses for descriptive statistics were performed by box plots and histograms; for inferential statistic of small sample size, the non-parametric unbalanced Kruskall Wallis test was applied. Statistical significance was assumed with a p-value < 0.05.

RESULTS

Macroscopically, each septal infiltration resulted in localized mucosal swelling and wheal. Histologically, physical dissection

Table 1. Data of all specimens tested. Achieved level by hydrostatic dissection: a: above perichondrium, i: intra-perichondrial, sp: sub-perichondrial. Minimal mean value in μm between beginning of target subperichondrial zone and the beginning of ink marked dissection. Mean thickness of subperichondrial zone as averaged by measurements of 3 independent observers. Data in brackets are of specimens with gross pre-existing septal anomalies, which were excluded from further quantitative and statistical analysis.

n	age (years)	sex	surgeon	hydrodissection level	hydrodissection (μm)	subperichondrial zone (μm)	comment
1	92	m	PD	a	244	61	Slight tear artifact, calcified cartilage
2	83	m	PD	(a)	(314)	(53)	**old septal perforation**
3	50	m	PD	sp	38	74	
4	79	f	PD	sp	79	79	large cartilage tear
5	79	m	PD	i	116	53	ink marked injection canal
6	94	m	PD	i	205	63	interstitial ink accumulation
7	86	f	PD	a	152	32	ink intravascular
8	77	f	GM	(a)	(227)	(79)	**revision septoplasty**
9	84	f	GM	sp	57	76	
10	60	f	GM	a	827	79	
11	98	m	GM	i	60	53	ink in sinusoids
12	63	m	GM	a	248	74	ink intravascular
13	88	f	GM	sp	83	87	ink in sinusoids
14	76	m	MC	a	278	82	ink intense in sinusoids
15	88	m	MC	a	172	79	ink periglandular
16	67	m	MC	(i)	(103)	(79)	**old septal fracture**
17	98	f	MC	a	457	103	
18	84	f	MC	sp	28	58	ink intravascular, calcified cartilage
19	84	f	MC	i	96	56	ink intravascular, calcified cartilage
20	84	m	MC	a	217	50	ink in sinusoids

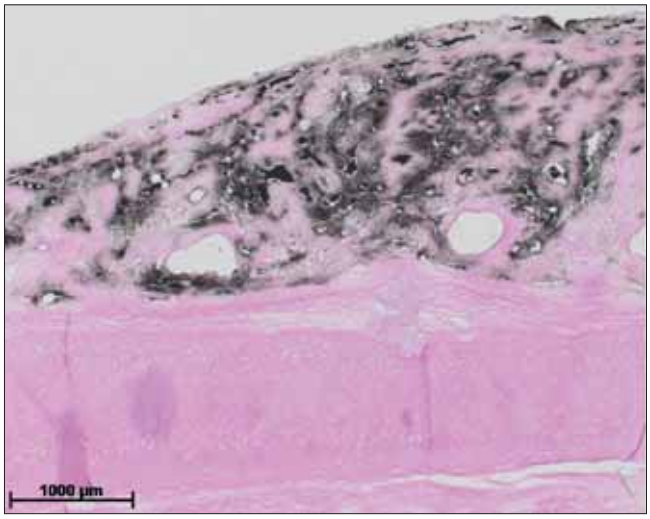

Figure 3. Spread of infiltrated black India ink to venous sinusoids of the septal swell body (3 µm section, Thiel fixed material, hematoxylin-eosin staining).

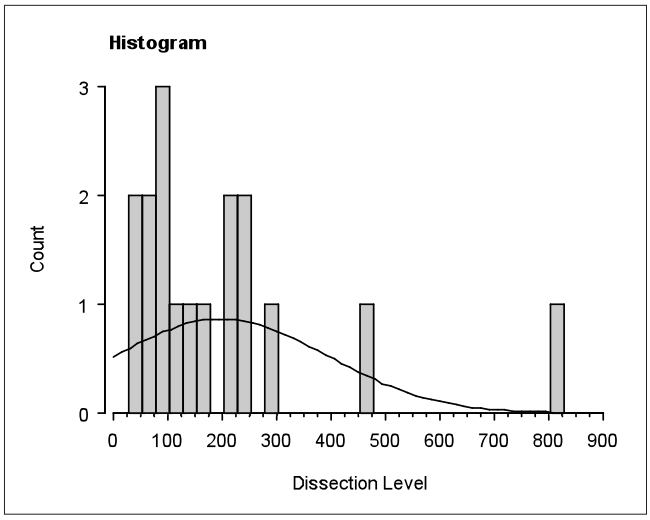

Figure 4. Histogram: Minimal values of the distance between dissection achieved and the target subperichondrial zone (Figure 3). Distribution in 25 µm intervals for all septa (n = 17) compared to calculated normal distribution in the background.

between different anatomical layers of the nasal septum was possible (n = 20). However, dissected planes showed random distribution mostly in the supra-perichondrial adjacent connective tissue layers (n = 8) or within the perichondrium (n = 4). Only five cases showed exact dissection in the subperichondrial zone (Figure 2). Three septa showed pre-existing anomalies of a septal fracture, perforation or septoplasty, which might explain why in those cases dissection, was only supra- (n = 2) or intraperichondrial (n = 1) and were excluded from further quantitative analysis. The success rate in producing a subperichondrial dissection plane was neither dependent on the surgeon nor on the needle thickness used (Table 1).

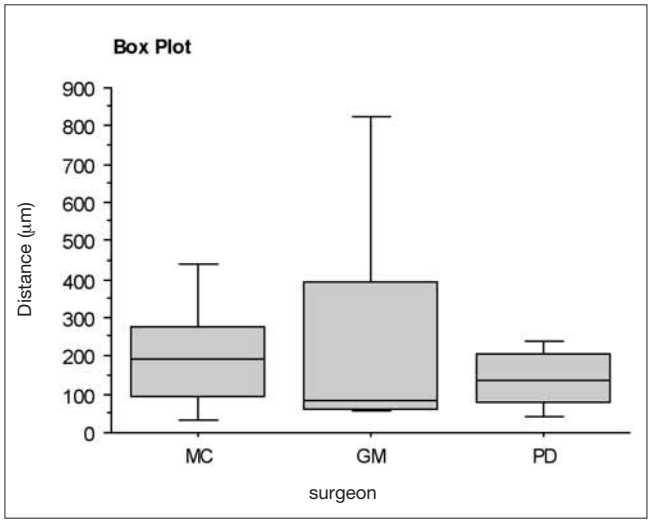

Figure 5. Box plots with range and mean values (line dividing the grey 25 to 75 percentile box) of the distance between the realized dissection and the target zone illustrating overlapping results for all 3 surgeons. Nonparametric statistical testing for small sample size did not point to differences between the three surgeons ($p > 0.05$, Kruskall-Wallis).

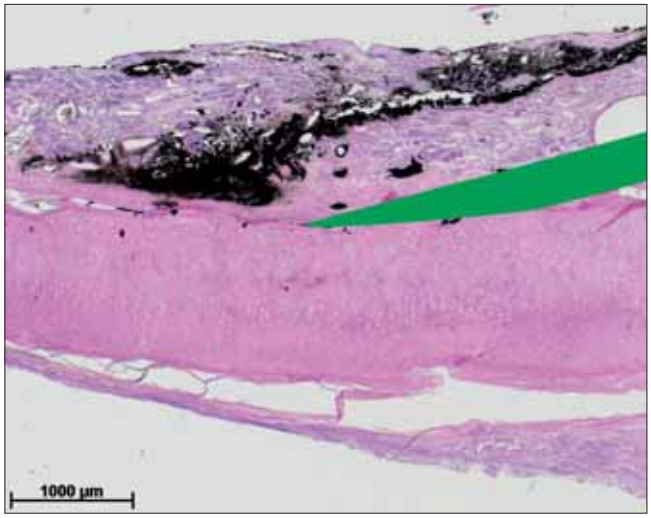

Figure 6. Histology of the human septal soft-tissue envelope (3 µm section, hematoxylin-eosin staining, Thiel fixed material) with destroyed columnar epithelial and endothelial components. Dimensional relation of the thin target subperichondrial zone compared to the 27-gauge needle (Green: needle tip of 0.4 mm outer diameter with cut surface parallel to the target zone). Black ink deposit in the puncture canal and distribution in the t-shaped, supra-perichondrial dissected tissue plane; hematoxylin-eosin staining.

Qualitative histological analysis based on Thiel fixed material and HE staining

The chondral components were very well appreciated (Figure 3) with only occasional occurrence of artificial tissue tearing. Connective tissue components such as collagen fibers, glandular elements and nerve fibers were also well preserved. However, the endothelium and columnar epithelial lining were not maintained. The destruction of those very fragile and only one or three cell layers thick tissue plains (vessel endothel and

nasal columnar ciliated epithelium, respectively) was a microscopic finding and had no influence on the overall tissue strength for macroscopic puncture and hydrodissection of the otherwise fully preserved soft tissue envelope.
The infiltrated ink did not only accumulate in the split connective tissue layers but also penetrated the surrounding vessels or sometimes the large sinusoids (Figure 3) of the septal swell body (n = 8, Table 1).

Quantitative morphometric analysis
For 17 septal specimens, mean values of the thickness of the subperichondrial zone was 68.2 μm (SD = 17.1, range = 32-103) measured at the point of minimal distance of the ink marked dissected plane to the subperichondrial target zone.
The minimal distance of ink-marked tissue cleavage to the beginning of the subperichondrial zone are tabulated (Table 1) and grouped together according to a 25 μm scale in levels superficial to the target surgical dissection plane. The resulting histogram suggests a random distribution of tissue cleavage by hydrodissection (Figure 4) and the box plots of the achieved minimal distances for the individual surgeons show an overlap (Figure 5). Mean values for the distance of the dissection plane with respect to the target subperichondrial zone was 197.5 μm (SD = 196, range = 28-827) and did not differ statistically between the 3 surgeons ($p > 0.05$, Kruskal-Wallis test).

DISCUSSION

This study tested experimentally the validity of hydrodissection for subperichondral septoplasty on the histological level. Experimental hydrostatic infiltration with the cannula tip in contact to septal cartilage did not result in a reproducible and reliable dissection in a subperichondrial zone. According to our data, proper dissection was only achieved in 5 of 17 cases excluding three more difficult cases with septal anomalies. Moreover, we confirm histologically the possibility of penetration of the injected material into the venous sinusoids and other surrounding vessels [18,19]. This distribution of hydrostatic injections with potential devastating side effects illustrates the risk associated with the use of high volumes of vasoconstrictive drugs and local anesthetics in the erroneous belief to elevate reliably the subperichondrial tunnels. As previously advocated by various investigators [2,6,20], we also recommend the use of only small infiltrated volumes (0.5 to 1 ml) and slow injection with careful aspiration and frequent pauses for monitoring of cardiovascular parameters.

Histological and electron microscopic studies of the normal anatomy of the septal perichondrial envelope show an intense interconnection between the cartilage and the perichondrium through collagen fibers supporting the particularly flexible function of the cartilage aspect of the nose [21,22]. On the other hand, the tight relation between septal cartilage and perichondrial tissue makes a clear and distinctive stratification in subperichondrial, perichondrial or supraperichondrial levels more difficult compared to other cartilaginous tissues in the human body [16]. On histological grounds, we could not define a clear-cut subperichondrial plane but had to refer to a subperichondrial zone, i.e. a zone tangentially between the last oval to spindle shaped chondrocytes and the beginning of the dense collagen fiber strands of the perichondrium.

Current study restraints include the rather limited availability of fresh cadaver heads at our institution for use in specific studies as the one described. Subsequently, we did not have 20 fresh cadaver heads at our disposal to perform the experiments under uniform conditions for the 3 rhinosurgeons at the same time. We therefore had to rely on the bodies donated to the Institute of Anatomy of the University of Berne collected over the period of one year using one of the most lifelike preservation techniques available. Tissue alteration related to the advanced age of the study population, the altered natural turgor and absence of vital tissue perfusion in the post mortem experiment might have had an influence on the results. Although a growing number of macroscopic studies take advantage of the lifelike preservation by Thiel fixation [23,24], experiences and data on the histological level are still sparse. The Thiel fixation provides natural and well-preserved connective tissue characteristics but destroys the endothelial and most superficial columnar epithelial cells. This fact may lead to an overestimation of intravascular spread of injected material due to the lack of intact natural barriers. However, destruction of the anyway thinnest and most fragile part of the nasal mucosa has no influence of the quality of the soft tissue envelope for our macroscopic surgical experiments.

The ideal purpose of creating a hydrostatic subperichondrial dissection plain in septoplasty is to facilitate surgical dissection with minimal hemorrhage in an avascular zone [25] and to preserve as much soft tissue envelope as possible for further stable wound closure. The empirical results of this histological study support one of the existing hypotheses [7] that with a needle much larger than the subperichondrial target zone itself, controlled dissection of that plane is not feasible (Figure 6).

CONCLUSION

The paradigm of subperichondrial dissection in septoplasty relies on the idea of a surgical dissection plane; in reality, a virtual subperichondrial space, allowing preservation of the soft tissue envelope and resection in a relatively avascular zone. For realization of this ideal, pressure hydrodissection is not a reliable tool, but might be useful for hemostatic and anesthetic reasons.
Disagreeing with excessive septal infiltrations by local anesthetics and adrenalin for an unreliable dissection technique, we recommend the careful administration of only small single doses adequate for hemostasis and local anesthesia only, minimizing the risk of side effects.

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