Peribulbar versus Retrobulbar Anesthesia for Ophthalmic Surgery

An Anatomical Comparison of Extraconal and Intraconal Injections

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Background: Peribulbar and retrobulbar anesthesia have long been opposed on the basis of the existence of an intermuscular membrane, which is supposed to separate the intraconal from the extraconal spaces in a water-tight fashion. A local anesthetic injected outside the cone should spread through this septum to reach the nerves to be blocked. The existence of this septum is questioned. The aim of this study was to compare the spread of a colored latex dye injected intraconally or extraconally to simulate both retrobulbar and peribulbar anesthesia.

Methods: The authors used 10 heads from human cadavers. For each head, one eye was injected intraconally, and the other eye was injected extraconally. The heads were then frozen and sectioned into thin slices following various planes. They were then photographed and observed.

Results: There was no evidence of the existence of an intermuscular septum separating the intraconal and extraconal spaces. Those two spaces appeared to be part of a common spreading space, the corpus adiposum of the orbit.

Conclusions: These results are in accord with the fact that clinical studies were not able to clearly demonstrate that retrobulbar anesthesia is more efficient than peribulbar anesthesia. On the basis of a similar clinical efficacy of the two techniques as a result of similar spreading of the local anesthetic injected, and a potentially higher risk of introducing the needle into the muscular cone, the authors recommend replacing retrobulbar anesthesia with peribulbar anesthesia.

REGIONAL anesthesia is standard for most ophthalmic procedures. Retrobulbar anesthesia (RBA) has long been the choice technique for ophthalmic surgery.1–4 It consists of injecting a small volume of local anesthetic (3–4 ml) into the muscular cone. To prevent blinking, an additional facial nerve block is required to obtain akinesia of the orbicularis muscle of the lid, the only muscle of which motor innervation is located outside the cone. However, complications of RBA have led many anesthesiologists to turn to peribulbar anesthesia (PBA). PBA, which consists of introducing a needle into the extraconal space, should theoretically be safer than RBA. PBA was formally described in 1965.5–8 It is based on the “tissue compartment principle”9: “a needle is inserted into a compartment and the local anesthetic injected spreads by virtue of its pressure and volume throughout the compartment.” A relatively high volume of local anesthetic is injected into the extraconal space (usually 8–12 ml). The local anesthetic injected into the extraconal space must spread to the intraconal space to provide adequate anesthesia and akinesia of the globe. RBA and PBA have been opposed on the basis of the existence of the so-called intermuscular membrane (IMM) (fig. 1) which is supposed to separate the intraconal space from the extraconal space in a watertight fashion. Anatomically, this membrane, as a barrier impairing the spread of the local anesthetic, should make PBA less efficient than RBA. However, the reality of the existence of this septum remains controversial.10,11 From a clinical point of view, there is a lack of evidence to assume that RBA is more efficient than PBA.12–20 Moreover, in an anatomic study in live patients, Ropo et al.21 demonstrated that the local anesthetic injected into both spaces (ie, intraconal and extraconal) was able to flow freely from one space to the other. Ortiz et al.22 found similar results using tomodensitometry in human cadavers. The aim of this anatomic study performed on human cadavers was therefore conducted to describe precisely and compare the spread of a solution injected using both techniques and to assess precisely the existence—or not—of the IMM.

Materials and Methods

Injections

Ten human heads separated from the trunks were used. For each head, two different injections of a colored latex dye were randomly performed. One eye was allocated to receive an extraconal injection simulating PBA (five right eyes and five left eyes), and the other eye was allocated to receive an intraconal injection simulating RBA (five right eyes and five left eyes). All injections were performed by the same anesthesiologist (J. R.) experienced in both techniques in live patients and cadavers. All of the RBA injections were performed at the same site, using the technique described by Hamilton.2 A transcutaneous approach of the needle was used instead of a transconjunctival approach. A 30-mm 24-gauge needle was bent at 15 mm from the bevel at an
angle of 10°. The needle was inserted at the junction of the lateral and the medial thirds of the margin of the orbital floor on a vertical line drawn from the lateral part of the iris. It was advanced posteriorly to 15 mm and then redirected slightly medially and upward to 30 mm, where 4 ml latex dye was injected. We chose a 24-gauge instead of the more frequently used 25-gauge needle because of the viscosity of latex, which occasionally polymerizes and obstructs smaller needles. All of the PBA injections were performed using a 24-gauge 25-mm needle, with a volume of 6 ml, using the three different sites of introduction of the needle commonly used in current practice. Four injections were performed at the inferotemporal site, which is the same site as for RBA.

Table 1. Peribulbar (Extracone) Injections: Spread of the Latex

<table>
<thead>
<tr>
<th>Head No.</th>
<th>Side</th>
<th>Injection</th>
<th>Plane of Sections</th>
<th>Diffusion Score</th>
<th>IFS</th>
<th>Comments</th>
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<td>H</td>
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<td>1</td>
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<td>MC</td>
<td>S</td>
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R = right eye; L = left eye; IT = inferotemporal; SN = superonasal; MC = medial canthus; H = horizontal (transverse) section; C = coronal (frontal) section; S = sagittal section; IMMS = intermuscular membrane score (from 0 [evidence there is no membrane in the four quadrants] to 8 [total evidence there is a barrier to the dye spread at the supposed place where the septum lies]); diffusion score = presence of latex in the space not injected (i.e., extracranial space); IFS = intracone filling score by latex (0 = total or massive, 1 = incomplete or partial, 2 = not at all). For details, see text.

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Table 2. Retrobulbar (Intracone) Injections: Spread of the Latex

<table>
<thead>
<tr>
<th>Head No.</th>
<th>Side</th>
<th>Injection</th>
<th>Plane of Sections</th>
<th>Diffusion Score</th>
<th>IFS</th>
<th>Comments</th>
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</table>

All injections were performed using the same approach, i.e., inferotemporal. L = left eye; R = right eye; H = horizontal (transverse) section; C = coronal (frontal) section; S = sagittal section; IMMS = intermuscular membrane score (from 0 [evidence there is no membrane in the four quadrants] to 8 [total evidence there is a barrier to the dye spread at the supposed place where the septum lies]); diffusion score = presence of latex in the space not injected (i.e., extracranial space); IFS = intracone filling score by latex (0 = total or massive, 1 = incomplete or partial, 2 = not at all). For details, see text.

Anatomic Technique

Immediately after the end of the injection, the heads were deeply frozen at a temperature of −18°C for 48 h.

Table 3. Comparison of IFS after Retrobulbar (Intracone = RBA) and Peribulbar (Extracone = PBA) Injections

<table>
<thead>
<tr>
<th>Head No.</th>
<th>Side of RBA Injection</th>
<th>Site of PBA Injection</th>
<th>Plane of Sections</th>
<th>IFS:RBA</th>
<th>IFS:PBA</th>
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<td>L</td>
<td>IT</td>
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<td>0</td>
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</table>

All RBA injections were performed using the same approach, i.e., inferotemporal. The PBA injections used three different approaches: inferotemporal (IT), superonasal (SN), and medial canthus (MC).

L = left eye; R = right eye; H = horizontal (transverse) section; C = coronal (frontal) section; S = sagittal section; IFS = intracone filling score by latex (0 = total or massive, 1 = incomplete or partial, 2 = not at all). For details, see text.
Fig. 2. Human head injected with blue latex (no. 4): coronal section passing just posterior to the posterior pole of the eyeball (similar to fig. 1). (A) Right orbit injected with 3.5 ml into the intraconal space via an inferotemporal approach (retrobulbar anesthesia). (B) Left orbit injected with 6 ml latex into the inferotemporal quadrant of the extraconal space (peribulbar anesthesia). (A' and B') Semischematic view of A and B with the superimposed place where the intermuscular membrane should be (dotted line). * = Approximate site of injection; 1 = optic nerve; 2 = lateral rectus muscle; 3 = inferior rectus muscle; 4 = medial rectus muscle; 5 = superior rectus muscle–levator palpebrae superioris muscle complex; 6 = superior oblique muscle. Note the spread of latex from one space to the other, through the supposed intermuscular membrane, resulting in a very similar picture after both injections.

Fig. 3. Human head injected with blue latex (no. 3): sagittal section passing through the eyeball, just laterally to the optic nerve. (A) Right eye injected with 3.5 ml into the intraconal space via an inferotemporal approach (retrobulbar anesthesia). (B) Left orbit injected with 6 ml latex into the inferotemporal quadrant of the extraconal space (peribulbar anesthesia). (A' and B') Semischematic view of A and B with the superimposed place where the intermuscular membrane should be (dotted line). 1 = superior rectus muscle–levator palpebrae superioris muscle complex; 2 = lateral rectus muscle (sectioned); 3 = inferior oblique muscle (outside the cone). Note the spread of latex from one space to the other, through the supposed intermuscular membrane, resulting in a very similar picture after both injections.

Fig. 4. Human head injected with blue latex (no. 7): sagittal section passing through the eyeball and the optic nerve. (A) Left orbit injected with 4 ml into the intraconal space via an inferotemporal approach (retrobulbar anesthesia). (B) Right orbit injected with 6 ml of latex via the superonasal quadrant of the extraconal space (peribulbar anesthesia). (A' and B') Semischematic view of A and B with the superimposed place where the intermuscular membrane should be (dotted line). 1 = optic nerve; 2 = inferior rectus muscle; 3 = superior rectus muscle–levator palpebrae superioris muscle complex; 4 = lateral rectus muscle (cross-sectioned). Note the spread of latex from one space to the other, through the supposed intermuscular membrane, resulting in a very similar picture after both injections.
or more. They were then sliced with an electric saw in 5-mm sections in various planes: three in a horizontal plane (one for each site of PBA injections), three in a sagittal plane (one for each site of PBA injections), and four in a coronal plane (two for inferotemporal site, one for superonasal, and one for medial canthus). Therefore, for each site of injection of PBA, there were at least three eyes injected and cut following the three different planes. For each head, the eye injected using the RBA technique was cut following the same plane as the second eye injected with PBA. They were then rewarmed to ambient temperature, washed, photographed, and observed.

Analysis of the Anatomic Views

Three scores were used for the analysis of the spread. All were scored by two independent investigators (J. R. and another anesthesiologist who was not involved in the study and who was unfamiliar with eye blocks). IMM score was used to quantify the evidence of the IMM existence for each eye. A 0–2-point scale was used for each of the four quadrants (A = superotemporal; B = superonasal; C = inferonasal; D = inferotemporal): 0 = evidence of inexistence of the IMM (free spreading of the dye clearly identified from one space to the other); 1 = no evidence of the existence or absence of the IMM (unclear spread or no dye in this quadrant); and 2 = evidence of the existence of the IMM (spreading of the dye from one space to the other clearly impaired by a barrier located on the supposed place of the IMM with stagnation of the dye on the border of this barrier). The global IMM score was the sum of the four quadrants scores and ranged from 0 (total evidence of inexistence of the septum) to 8 (total evidence of the existence of the septum). Regarding the final location of the dye, for each eye, the spreading of the dye from the space where it was injected to the other space was scored as follows: 0 = massive; 1 = moderate or partial; 2 = not at all, whatever the track identified for this spread. This was scored to compare the pertinence of the opposition between the two techniques of injections (RBA and PBA). Finally, as an index corresponding to clinical efficacy, the presence or absence of latex dye in the muscular cone was assessed using the intraconal filling score: 0 = massive or total filling of the intraconal space by the latex dye; 1 = partial or incomplete filling of the intraconal space by the latex dye; 2 = absolutely no latex in the intraconal space.

Statistical Analysis

Comparison of intraconal filling score between intraconal and extraconal injections was performed with the chi-square test.

Results

The site of injection was identified as being well located in all but three cases, which were excluded from the analysis: in one case of RBA (no. 8), the injection was inadvertently performed extraconally; in one case of RBA, although the injection was located in the attended space, an intravenous injection precluded any other spread of the latex (no. 5); in the third case, because of an unsuspected fracture of the orbital floor, the needle took a false track, resulting in an injection in the maxillary sinus (no. 6).

In one case (PBA no. 2), although the injection was located in the right space, it appeared that part of the latex was injected intravenously, with subsequent spread to the cavernous sinus. This case was not excluded from the analysis because part of the latex spread into the extraconal space. No intraarterial injection was identified. In two cases, some latex was found in the sheath of the lateral rectus muscle: one RBA (no. 1) and one PBA (no. 6), possibly indicating an intramuscular injection. In no case was a brain-stem spread of the dye identified.

Tables 1 and 2 summarize the scores of latex spread after simulated PBA and RBA, respectively. Table 3 shows the individual comparisons of intraconal filling score between RBA and PBA injections. The only statistical comparison was intraconal filling score, which showed no significant difference between the filling of the intraconal space after both RBA and PBA. In no case was there clear evidence of an IMM impairing spread of the latex: all individual IMM scores were less than 3, except for one that was 4 (RBA no. 10). In the latter case, the score was 1 (no evidence or unclear) for each quadrant.

Three views of both eyes of the same heads showing typical spread of the dye are shown in figures 2–4. In all cases of RBA and PBA, the spread of the dye from the injection site was observed in all directions of the space. It was mainly guided by the small septa network that segments the whole adipose tissue of the orbit. There was no evidence of the existence of any intermuscular septum that clearly separated the intraconal and extraconal spaces. In fact, the final location of the dye was very similar between PBA and RBA. In all the injections but one PBA (no. 10), there was a spread from one space to another through the gaps between the adjacent pairs of rectus muscles. It appeared that the intraconal and extraconal spaces are not separated, but rather are two parts of one single space, the corpus adiposum of the orbit. In all cases, spread of the dye appeared to be caused by pressure of injection and guided only by the septa framework in all directions of the space, with an uncertain pattern, sometimes filling the whole orbit and sometimes not.

Discussion

In this anatomic comparison between retrobulbar and peribulbar injections, we were unable to confirm the existence of any intermuscular septum separating intraconal from extraconal spaces. The colored dye spread...
very similarly after both injections throughout the adipose tissues of the orbit in an uncertain and sometimes heterogeneous fashion.

**Extrapolation from Cadaver to Live Patients**

Some concern may be expressed about extrapolating results from cadavers to live patients. In fact, the anatomy is the same. The high viscosity of latex led us to use needles of relatively large diameter that are currently used in live patients. A second problem is that the latex we used was more viscous than the local anesthetic mixture and quickly polymerizes after injection and becomes unable to spread, whereas local anesthetic may continue to spread over a few minutes. Therefore, latex might spread incompletely. In fact, in two previous studies, we injected orbits of human cadavers with similar latex and fluid hydrophilic contrast media for tomodensitometry, respectively. The conclusions of those two studies were very similar, with the exception of a complete spread of the dye with the contrast media than with latex. Therefore, if there is a difference of spread caused by viscosity of the latex dye, it is more limited with latex than with local anesthetic. This should not modify our conclusions. Another frequently used colored dye is methylene blue, which spreads very easily throughout adipose tissues. Hustead et al. performed such an injection, which resulted in an orbit totally filled with blue: "...the dye has distributed throughout most of the orbit. Neither the needle track nor the point of injection can be deduced." We felt that using a very fluid solution would not be discriminative enough to identify an IMM if it exists.

**Effect of Volume**

One can argue that we did not inject the same volume in RBA than in PBA. Those volumes were determined from current clinical practice. Indeed, all the nerves responsible of the sensory, motor, and autonomic innervation of the eyeball transit through the intraconal space, with the exception of the branch of the facial nerve, which is responsible for the motor innervation of the orbicularis muscle of the lids. Therefore, the local anesthetic injected via any technique (i.e., RBA or PBA) must spread into the cone to block them. That is why the local anesthetic injected extraconally has a longer way to spread from the site of injection to the target nerves to be blocked. Obviously, increasing the volume injected is a means of compensating for this need for more spreading.

**Complications**

One point of interest is intravenous injection with subsequent filling of the cavernous sinus (10% both for RBA and PBA). Because of the low volumes used in eyes, an inadvertent intravenous injection is unlikely to produce signs of systemic toxicity. One can assume that such an intravenous injection is frequently unrecognized because of a lack of symptoms. By contrast, an intraarterial injection with a subsequent back flow to the internal carotid artery is a clearly identified complication. This generally leads to immediate seizures. Such an intraarterial injection was not identified in our work. Another complication is the occurrence of postoperative strabismus. We observed spread of the latex into the fascial sheath of a muscle in one case of RBA and in one PBA. We assumed that the risk for inadvertent injury to a rectus muscle remains significant for both techniques.

Although uncommon, many other complications have been described after PBA: ptosis, globe perforation, optic nerve injury, and brain-stem anesthesia. In the present study we did not observe an injection that might be correlated with one of these complications. All the complications were fist described after RBA, and subsequently after a PBA. Some of them obviously require the intraconal positioning of the needle and should not occur after PBA, such as optic nerve injury or arterial retrobulbar hemorrhage. This implies that some intended PBAs turn out, in fact, to be RBAs. Indeed, some techniques are not clearly identified as RBA or PBA, and provided that the needle is directed to the cone, changing its depth of insertion can change a PBA into a RBA. We did not encounter such a misplacement of the needle, but we experienced an inadvertent PBA in place of a intended RBA. Moreover, in one case of intended PBA, an inadvertent episcleral (sub-Tenon) injection was observed, which may occur in clinical practice without always being recognized as the only sign is the occurrence of a chemosis. Therefore, even when performing PBA, the needle is sometimes very close to the eyeball, which may be inadvertently perforated.

There are no comparative studies to confirm that complications occur less frequently with PBA than with RBA. This is probably because of the very low frequency of those complications, with a lack of power of small-sized comparative studies. Although this has to be confirmed, we assume that PBA should theoretically lead to a lower risk of complications.

**Clinical Implications: Compared Efficacy of Retrobulbar and Peribulbar Anesthesia**

The main finding of this work was to confirm that PBA and RBA correspond to the same final location of the local anesthetic. This is in agreement with the results of Ropo et al., who described the same spread after PBA and RBA in live patients using computed tomodensitometry. Ortiz et al. found similar results after injecting a simulated PBA in cadavers and evaluating the spread of the dye using tomodensitometry. Moreover, increasing the volume injected with the RBA technique may provide an efficient motor blockade of the orbicularis of the lids. This implies that the local anesthetic spreads through the extraconal space before reaching...
the lids, as after PBA. Many investigators are convinced, mainly based on personal experience or retrospective nonrandomized studies, that RBA is more efficient than PBA.\textsuperscript{6,14,29} However, to our knowledge, most randomized studies were not able to clearly demonstrate a benefit of RBA over PBA in terms of akinesia or onset of block. Ali-Melkkilä \textit{et al.}\textsuperscript{38} compared RBA and PBA in 300 patients and found rates of additional block of 13% and 35%, respectively. In another similar study, the same investigators were unable to confirm these results, with rates of re-injection between 11% and 19%.\textsuperscript{12} Demediuk \textit{et al.}\textsuperscript{13} observed rates of need for re-injection of 31% and 33% after PBA and RBA, respectively. Murdoch\textsuperscript{15} found a 3% rate of unsatisfactory blocks after PBA as compared with 10% with RBA. Saunders \textit{et al.}\textsuperscript{16} failed to find a difference of efficacy between RBA and PBA, as did Shriver \textit{et al.},\textsuperscript{17} who found rates of re-injection of 4.4% and 6.8% for RBA and PBA, respectively. Similarly, no difference was observed by Weiss and Deichman,\textsuperscript{18} with re-injection rates of 28% for PBA and 21% for RBA. Finally, Whitsett \textit{et al.}\textsuperscript{19} found no difference between PBA and RBA, with re-injection rates of 11% and 8%, respectively. The fact that the re-injection rate varies in these series from 4% to 28% is not surprising. Those variations probably reflect the fact that the efficacy of the blocks is operator-dependent rather than technique-dependent, and especially that the exigency of the surgeon regarding total akinesia may vary dramatically from one institution to another. However, the absence of clear evidence of difference between the two techniques is in agreement with the same spread of the dye after both techniques we observed in our study.

In conclusion, our work confirms that intraconal and extraconal spaces largely communicate. In fact, RBA and PBA correspond to the same spread of the dye. This is in agreement with a similar efficacy of both techniques observed in clinical practice. Theoretically, the puncture risk is lower in PBA than in RBA. Therefore, the combination those two facts should be considered as an argument for replacing RBA with PBA in current practice.

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References