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THE HYUGONI® APPROACH TO CONTINUOUS LOCOREGIONAL ANESTHESIA IN PENETRATING KERATOPLASTY: TECHNICAL DESCRIPTION AND CLINICAL OUTCOMES UNDER ULTRASOUND GUIDANCE

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ARTIGO ORIGINAL

RESUMO

Introdução: A ceratoplastia penetrante (CP) é um procedimento de transplante de córnea de espessura total que exige um manejo anestésico preciso, particularmente dado o risco de flutuações da pressão intraocular em um cenário de globo aberto. Objetivo: Descrever uma técnica anestésica peribulbar contínua utilizando uma cânula flexível de ponta romba guiada por ultrassom (Hyugoni®, 25G) e avaliar sua segurança e eficácia em pacientes submetidos à ceratoplastia penetrante. Métodos: Uma série de casos retrospectiva foi conduzida envolvendo 362 pacientes adultos consecutivos que foram submetidos à CP sob bloqueio peribulbar contínuo com sedação leve em um único centro oftalmológico entre dezembro de 2019 e dezembro de 2023. Resultados: A técnica proporcionou anestesia eficaz com um volume médio total de anestésico local de 7,97 ± 4,1 mL. Suplementação intraoperatória foi necessária em 16,0% dos pacientes, e sedação adicional em 11,6%. Nenhuma complicação cirúrgica grave foi registrada. Conclusão: O bloqueio peribulbar contínuo guiado por ultrassom com a cânula Hyugoni® demonstrou um perfil favorável de segurança e eficácia.

Palavras-chave: Anestesia peribulbar, Ceratoplastia penetrante, Ultrassom, Cânula flexível, Hyugoni.

ABSTRACT

Background: Penetrating keratoplasty (PK) is a full-thickness corneal transplantation procedure that demands precise anesthetic management, particularly given the risk of intraocular pressure fluctuations in an open-globe setting. Objective: To describe a continuous peribulbar anesthetic technique using an ultrasound- guided flexible blunt cannula (Hyugoni®, 25G) and to evaluate its safety and effectiveness in patients undergoing penetrating keratoplasty. Methods: A retrospective case series was conducted involving 362 consecutive adult patients who underwent PK under continuous peribulbar block with mild sedation at a single ophthalmic center between December 2019 and December 2023. Results: The technique provided effective anesthesia with a mean total local anesthetic volume of 7.97 ± 4.1 mL. Supplemental intraoperative anesthetic was required in 58 patients (16.0%), and additional sedation in 42 patients (11.6%). No severe surgical complications were recorded. Conclusion: Ultrasound-guided continuous peribulbar block with the Hyugoni® cannula demonstrated a favorable safety and effectiveness profile, enabling surgical anesthesia with low total anesthetic volumes and minimal rescue requirements.

Keywords: Peribulbar anesthesia, Penetrating keratoplasty, Ultrasound, Flexible cannula, Hyugoni.

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1 INTRODUÇÃO

The cornea is a complex ocular structure that, beyond serving a protective role for the eye, is responsible for approximately two-thirds to three-quarters of its total optical power.[1] Its layers, from anterior to posterior, are: epithelium, Bowman's layer, stroma, Descemet's membrane, and endothelium.[1] This tissue is avascular; nutrients are supplied and metabolic waste removed by the aqueous humor posteriorly and the tear film anteriorly.[1] As the most densely innervated tissue in the human body, pathological conditions affecting the cornea — such as perforations and bullous keratopathy — are associated with moderate to severe pain, reflex tearing, and photophobia, often rendering clinical examination of affected patients challenging.[1]

Corneal transplantation, or keratoplasty, involves replacing pathological corneal tissue with healthy donor tissue.[1–4] Grafts may be partial — either anterior or posterior lamellar — or full-thickness (penetrating).[1–4] The four main clinical indications are: (1) optical, to restore visual acuity (e.g., keratoconus, corneal scars, stromal dystrophies, bullous pseudophakic keratopathy, and degenerations); (2) tectonic, to restore or maintain structural integrity (e.g., severe corneal thinning with descemetocele); (3) therapeutic, to remove infected corneal tissue unresponsive to antimicrobial therapy; and (4) cosmetic, to improve ocular appearance — a rare indication.[1–4]

Penetrating keratoplasty may be performed under peribulbar block with or without sedation, topical anesthesia, or general anesthesia.[5–7] Anesthetic planning must account for the risk of intraocular pressure elevation during regional anesthesia, which is particularly critical in the open-globe setting: with an open cornea, sudden rises in intraocular pressure may cause herniation of ocular contents, potentially resulting in loss of intraocular structures and irreversible vision loss.[5,8–13] For the same reason, external ocular compression — commonly employed after conventional peribulbar block to facilitate anesthetic dispersion — is specifically contraindicated in penetrating keratoplasty, as it may displace intraocular structures toward areas of lower resistance, compromising tissue integrity.[5,14–21]

Anesthetic management in this patient population can be particularly challenging due to the frequent presence of ocular inflammation, which impairs local anesthetic (LA) efficacy through multiple mechanisms.[5] Decreased local tissue pH increases block latency and shortens anesthetic duration by shifting the ionized-to-non-ionized drug ratio, thereby reducing membrane permeability and uptake.[5] Concurrently, vasodilation and increased vascular permeability induced by inflammatory mediators accelerate systemic absorption of the LA, further reducing local effect duration.[5] Since increasing LA volume carries the risk of intraocular pressure elevation, and ocular massage is contraindicated, adjuvant strategies — such as the addition of adrenaline, sodium bicarbonate, fentanyl, or clonidine — may extend block duration; however, even with adjuvants, anesthetic effect may remain insufficient for the full duration of the procedure.[5,22]

To maintain a stable LA concentration sufficient for surgical anesthesia — without inducing abrupt intraocular pressure rises — an alternative strategy is the intermittent

intraoperative administration of small anesthetic volumes at fixed intervals. For this purpose, we employed a flexible blunt cannula with a silicone extender (Hyugoni®, 25G; TY Care Indústria e Comércio Ltda., Brazil),[7] positioned immediately before surgery under ultrasound guidance via the medial canthus, enabling controlled, continuous intraoperative peribulbar anesthetic supplementation. The device was originally referred to as iCann® during the study period (December 2019 – December 2023); the current registered commercial name is Hyugoni® (TY Care Indústria e Comércio Ltda., Brazil), notified by Brazil's National Health Surveillance Agency (ANVISA) as a Class II medical device in March 2026,[7] and the inventor holds a pending utility model application before the Brazilian National Institute of Industrial Property (INPI).[26] This study describes the technique and its application in 362 consecutive penetrating keratoplasty cases, based on a retrospective chart review.

2 METODOLOGIA

This retrospective case series was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Ethics Committee. Medical records of 362 consecutive patients scheduled for penetrating keratoplasty (PK) at Hospital de Olhos de Caxias (Municipal Hospital Júlio Cândido de Brito, Duque de Caxias, Rio de Janeiro, Brazil) between December 2019 and December 2023 were reviewed. This study was reported in accordance with the STROBE guidelines for observational studies.

Inclusion criteria were: age 18 years or older; indication for corneal transplantation by penetrating keratoplasty; use of locoregional anesthesia as the primary anesthetic technique; absence of prior hypersensitivity reactions to iodine or seafood; and availability of complete medical records with signed surgical, anesthetic, and research consent forms. Exclusion criteria were: use of general anesthesia as the primary technique; age under 18 years; history of hypersensitivity to iodine or seafood; incomplete medical records; and absence of any required signed consent form.

All patients underwent surgery in na outpatient setting. The anesthetic technique evaluated in eligible subjects was continuous peribulbar block with mild intravenous sedation. Prior to the procedure, all participants received a thorough explanation of the technique, including discussion of risks, benefits, and alternatives. Written anesthetic-surgical informed consent was obtained from all participants, along with specific consent for anonymized data use in research.

Anesthetic Technique

Prior to the block, all patients received intravenous sedation with diazepam (0.1 mg/kg) and fentanyl (0.5 µg/kg), supplemental oxygen via nasal cannula at 2 L/min, and topical instillation of one drop of sterile 0.5% proparacaine in the operative eye. All blocks were performed with the patient in the supine position. A sterile flexible blunt cannula (Hyugoni®, 25G; TY Care Indústria e Comércio Ltda., Brazil)[7,26] was used, specifically designed for continuous anesthetic delivery via repeated small-volume injections.

Ultrasound imaging was performed using a 14 MHz linear transducer (Mobisson® M4, wireless; Mobisson Ultrasound, Brazil), positioned horizontally over the upper eyelid to generate a transverse scan at the 9 o'clock position for the right eye and the 3 o'clock

position for the left eye, with minimal transducer pressure to preserve image quality and avoid inadvertent globe compression.

The cannula was introduced via subcaruncular puncture in the operative eye. Under continuous ultrasound guidance, the following orbital structures were systematically identified: the globe, the ocular muscle cone, the medial rectus muscle tendon, and the medial orbital wall. A solution of 0.75% levobupivacaine combined with hyaluronidase 1.0% was then slowly injected under real-time visualization, allowing direct confirmation of cannula placement within the retrobulbar intraconal space. Correct positioning was confirmed by three concurrent findings: (1) slight displacement of orbital structures in the direction contralateral to injection; (2) anterior globe displacement; and (3) the appearance of a specific intraconal hypoechogenic signal (HS). The width of the HS was measured in millimeters, and the anesthetic volume required to generate it was recorded for each patient.

Following anesthetic injection, patients were assessed for sensory and motor block adequacy using a standardized grading scale (Table 1).[25] If a sensory block grade of +2 or higher was confirmed, the cannula was secured in place and surgery commenced. If the assessed grade fell below this threshold, an additional volume corresponding to half the initial HS-generating dose was administered, followed by reassessment. This titration process was repeated until the target block grade was achieved before proceeding to surgery.

Grade	Response
0	No anesthetic effect
+1	Mild anesthetic effect; pain present but reduced
+2	No pain; proprioception preserved
+3	No pain, no proprioception

Table 1. Grading scale for sensory anesthetic effect, as described by Siqueira et al. (2022).[25] Block assessment is performed by instillation of 5% povidone-iodine eyedrops in the operative eye, with the patient's response graded according to the scale below.

According to the study protocol, intraoperative anesthetic supplementation was initiated after placement of the second corneal suture, with 1 mL of the anesthetic solution administered via the cannula. Thereafter, 1 mL boluses were repeated every 30 minutes, or immediately upon patient-reported discomfort, whichever occurred first. Patients were maintained at a Richmond Agitation-Sedation Scale (RASS) score of 0 throughout the procedure. Additional rescue medications were administered at the attending physician's discretion in response to patient complaints, as follows: propofol (0.2 mg/kg IV) for RASS scores above 0; fentanyl (0.25 µg/kg IV) for pain; or an additional 1 mL bolus of anesthetic solution via the cannula for reports of proprioception or local discomfort. All pharmacological interventions were prospectively recorded in the standardized anesthesia record.

Continuous variables are expressed as mean ± standard deviation (±SD) or median [interquartile range (IQR)], according to distribution normality assessed by the Shapiro-Wilk test. Proportions are expressed as absolute frequency/total (percentage; 95% confidence interval calculated by the Wilson method).

Variable definitions:

N: total number of patients included
Age: mean age of the total sample (years)
Gender (F/M): gender distribution based on hetero- and self-identification; F = female, M = male; no participants self-identified as non-binary or neutral
HS: mean width of the intraconal hypoechogenic signal (mm) observed on ultrasound during the first anesthetic bolus, used as a surrogate marker of correct cannula placement
ST: median surgical time (min), measured from blepharostat placement to removal
A1: mean volume of the first anesthetic bolus administered via Hyugoni® (mL)
A2: median intraoperative anesthetic volume (mL) administered via Hyugoni® according to the study protocol, after surgical clearance
AT: mean total anesthetic volume (mL) administered by end of surgery (A1 + A2 + any rescue boluses)
AS: number and proportion of patients requiring anesthetic supplementation beyond protocol during surgery
SS: number and proportion of patients requiring additional sedation during the procedure
PP: number and proportion of patients requiring anesthetic infusion for postoperative pain prior to discharge

Unless contraindicated by a history of hypersensitivity to any of the agents, all patients received standardized perioperative intravenous therapy, comprising: antiemetic prophylaxis with ondansetron 8 mg and dexamethasone 4 mg; preemptive analgesia with dipyrone 2 g; and volume replacement with 500 mL of isotonic crystalloid solution. Additionally, all patients received intravenous mannitol at 1.5 g/kg approximately 30 minutes prior to surgical incision, to reduce intraocular pressure prior to globe opening.

3 RESULTADOS e DISCUSSÃO

Demographic and procedural data for all 362 patients are summarized in Table 2. Briefly, the cohort comprised 154 female and 208 male patients, with a mean age of 46 ± 14 years (range: 18–103). The primary outcomes — anesthetic volumes, intraoperative and postoperative rescue requirements, and adverse events — are described below.
A total of 362 consecutive patients were included, comprising 154 female and 208 male participants. Demographic and procedural data are summarized in Table 2. The mean surgical time was 100.6 minutes (IQR: 66–134; range: 35–216 minutes), reflecting the broad variability inherent to penetrating keratoplasty across different indications and surgical complexity levels.
Regarding anesthetic parameters, the mean width of the hypoechogenic signal at initial bolus was 4.76 ± 1.23 mm (range: 3.8–7.1), confirming consistent intraconal cannula placement across the cohort. The mean volume of the first anesthetic bolus required to achieve the HS and anterior globe displacement was 4.2 ± 1.2 mL (range: 1.8–6.1 mL). The median intraoperative supplementation volume administered according to protocol was 3.74 mL (IQR: 3.0–7.2; range: 1.0–18.0 mL), with a mean total anesthetic volume of 7.97 ± 4.1 mL (range: 3.8–24.0 mL) at the end of surgery.

Intraoperative rescue anesthetic supplementation beyond protocol was required in 58 patients (16.0%; 95%CI: 12.6–20.2%), most commonly due to proprioception (62%), followed by discomfort (20.6%) and pain (17.2%). Supplemental sedation was required in 42 patients (11.6%; 95%CI: 8.7–15.3%), primarily due to anxiety (54.7%), positional discomfort (33.3%), or significant agitation (11.9%). No patient required sedative doses sufficient to produce a RASS score below 0, indicating that adequate procedural sedation was maintained within the target range throughout.

At the end of surgery and prior to cannula removal, all patients were assessed for postoperative pain using the study's standardized protocol. In cases of reported pain, 1.5 mL of anesthetic solution was administered through the cannula, which was removed only after confirmation of pain resolution. Fourteen patients required this immediate postoperative infusion (3.9%; 95%CI: 2.3–6.4%), which was sufficient in all cases, with no further painful episodes reported prior to discharge.

All patients were discharged within 30 minutes of surgery with a post-anesthesia recovery score ≥ 9. No hypersensitivity reactions to local anesthetics or hyaluronidase were recorded. The overall incidence of anesthesia-related adverse events and intraoperative surgical complications was low, with no severe events reported in this series.

N	362
Age	46 +/- 14 (18-103)
Gender (F/M)	154/208
HS	4,76 +/- 1,23 (3,8-7,1)
ST	100,6 (35-216 [IQR 66-134])
A1	4,2 +/- 1,2 (1,8-6,1)
A2	3,74 (1,0-18,0 [IQR 3,0-7,2])
AT	7,97 +/- 4,1 (3,8-24,0)
AS	58/362 (16.0%; 95%CI: 12.6–20.2%)
SS	42/362 (11.6%; 95%CI: 8.7–15.3%)
PP	14/362 (3.9%; 95%CI: 2.3–6.4%)

Table 2. Patient demographic and procedural data extracted from surgical and anesthetic records (n = 362).

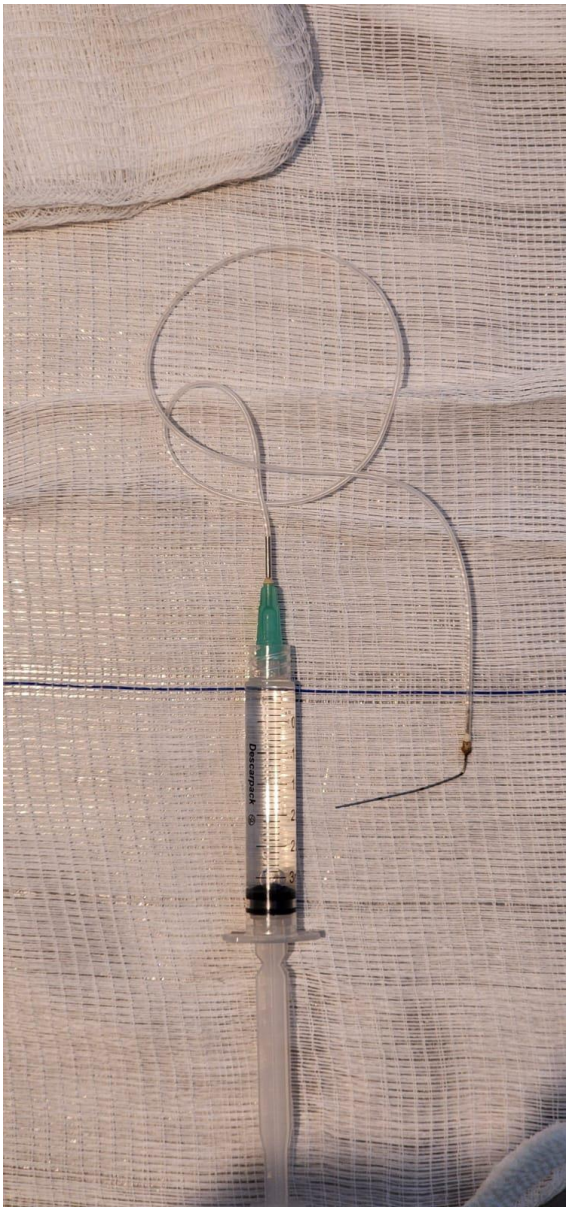

Figure 1. The Hyugoni® device (TY Care Indústria e Comércio Ltda., Brazil).[7] A sterile, flexible, 25-gauge blunt-tip cannula with silicone extender, assembled to a standard syringe for anesthetic delivery.

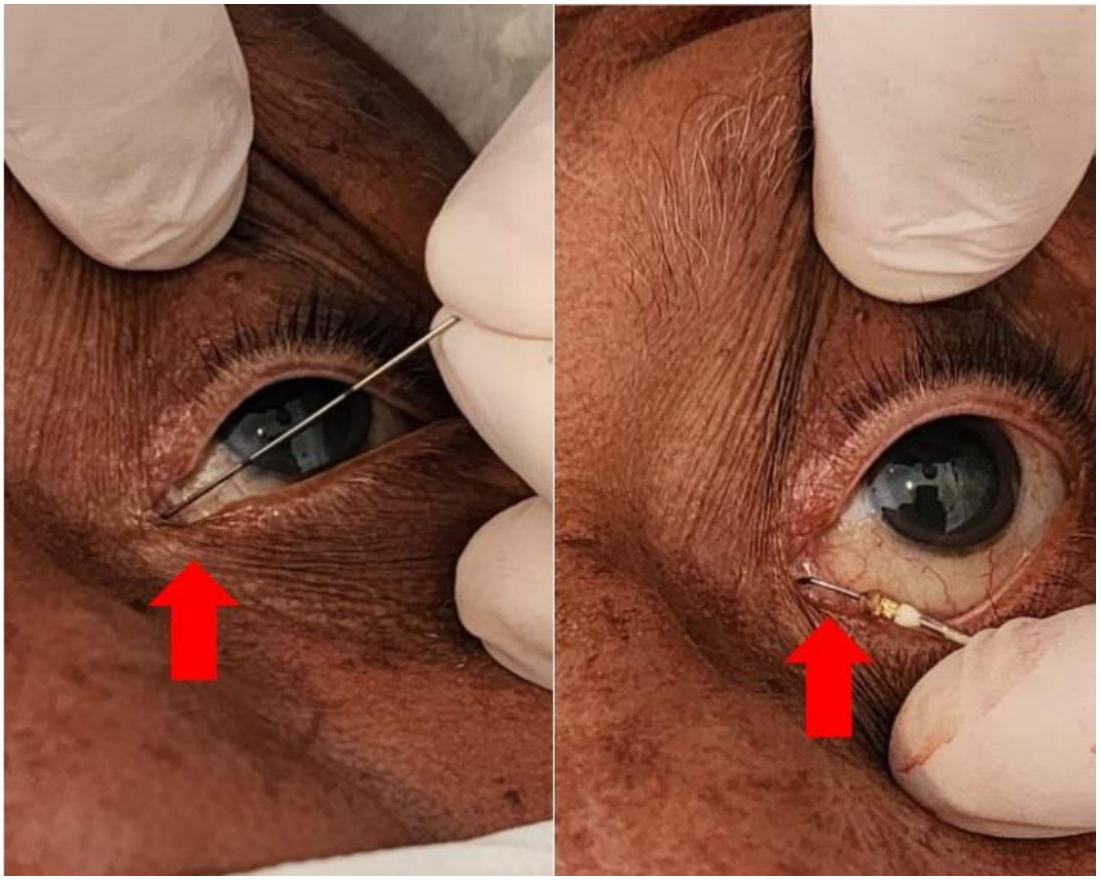

Figure 2. Subcaruncular insertion point of the Hyugoni® cannula (red arrow). The medial canthal approach via the caruncle allows access to the intraconal space while minimizing the risk of injury to the medial rectus muscle and the angular artery.[14]

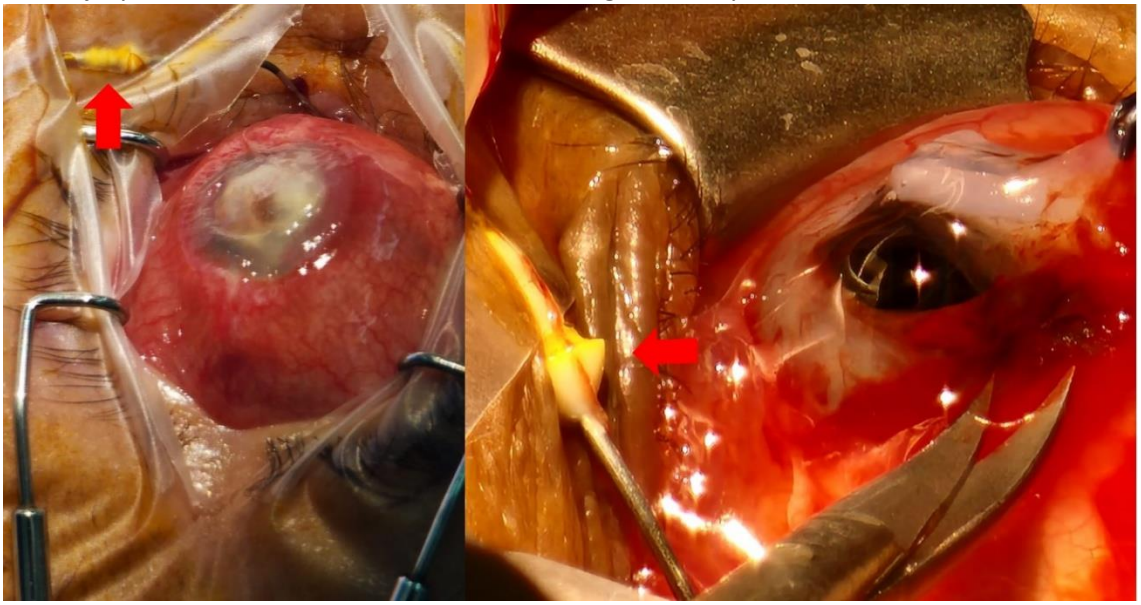

Figure 3. Intraoperative positioning of the Hyugoni® cannula (red arrow). The cannula remains secured in the subcaruncular access site throughout the procedure, enabling controlled intraoperative anesthetic supplementation via repeated small-volume boluses without repositioning or additional punctures.

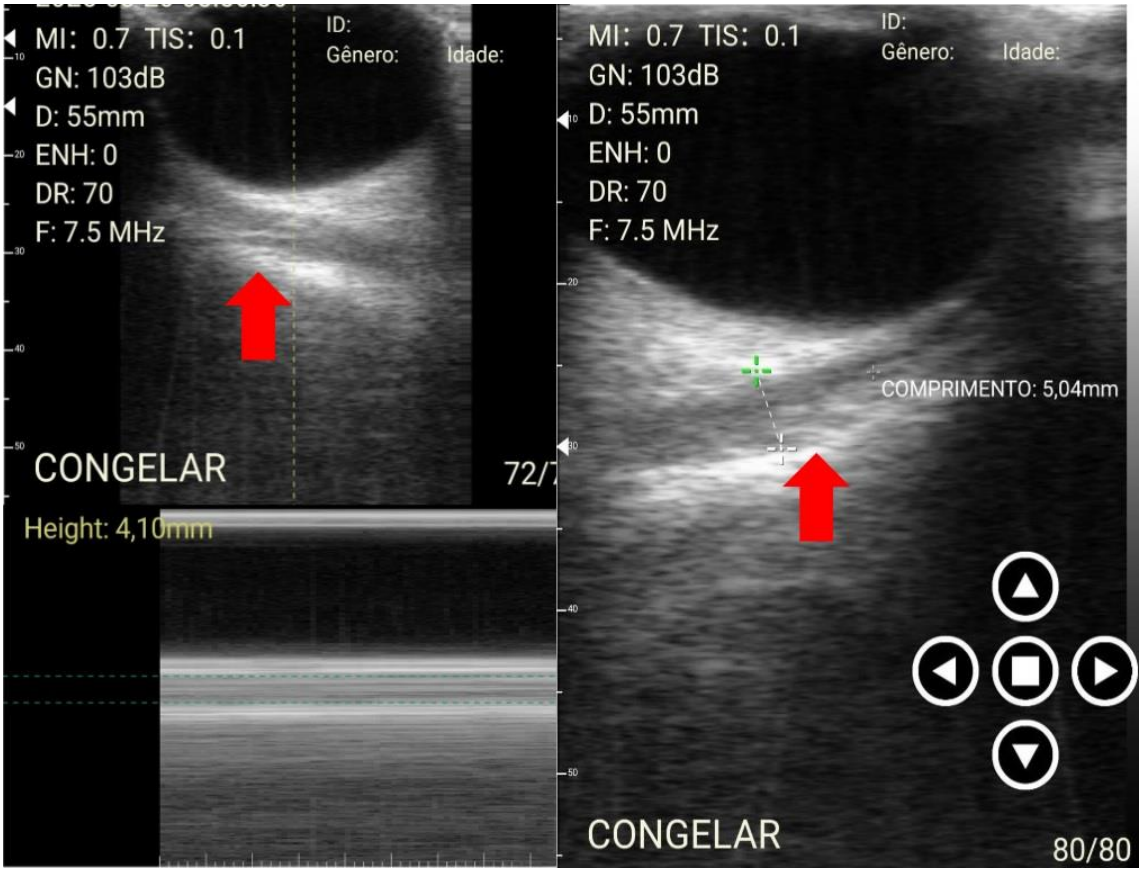

Figure 4. Ultrasonographic identification of the Hyugoni® cannula and intraconal hypoechogenic signal (HS; red arrow), acquired with the Mobisson® M4 wireless linear transducer (14 MHz). Left: B-mode image demonstrating the HS with an oblique width of 4.1 mm, confirming intraconal anesthetic deposition. Right: Standard transverse imaging at the 9 o'clock position (right eye), oriented from anterior to posterior, demonstrating the ocular globe, posterior sclera, and HS; the Hyugoni® cannula is visible as a thin hyperechogenic linear structure within the intraconal space.

Discussion

Locoregional anesthesia is a feasible and well-established technique for adult patients undergoing corneal transplantation, offering effective intraoperative and postoperative pain control while facilitating same-day discharge.[23,24] However, conventional needle-based peribulbar and retrobulbar blocks carry an inherent risk of sight- and life-threatening complications, including globe perforation, retrobulbar hemorrhage, optic nerve damage, and intrathecal spread of local anesthetic.[16,17] In the specific context of penetrating keratoplasty — an open-globe procedure — these risks are compounded by the susceptibility of intraocular contents to pressure-driven extrusion during anesthetic administration.[5] In this case series, the use of the intraoperatively positioned Hyugoni® cannula combined with ultrasound guidance was associated with a low total anesthetic volume requirement and a low incidence of technique-related adverse events.

A key safety advantage of the Hyugoni® device lies in its blunt-tip design, which eliminates the cutting edge inherent to conventional needles. Needle-based ophthalmic blocks carry a reported globe perforation risk of approximately 0.006–0.1%, a rate that increases substantially in eyes with axial lengths exceeding 26 mm or in the presence of

posterior staphylomas.[16,17] The absence of a sharp bevel in blunt cannulas reduces the likelihood of inadvertent vascular or globe injury during insertion and repositioning.[25] In a retrospective review of 1,089 consecutive cases using a similar blunt cannula technique under ultrasound guidance for cataract surgery, Siqueira et al. reported no globe perforations and no procedure cancellations due to anesthesia-related adverse events, with mild and tolerable side effects including chemosis (2.9%), hyposphagma (5.7%), and transient elevated intraocular pressure (7.5%).[25] In the present series, no hemorrhagic or globe-related complications were recorded, consistent with the favorable safety profile attributed to blunt cannula use.

The integration of ultrasound guidance represents a meaningful advancement over conventional landmark-based ophthalmic blocks. Traditional peribulbar and retrobulbar techniques are performed "blind," relying on external anatomical landmarks without real-time visualization of needle or cannula trajectory.[16] Ultrasound allows direct identification of key orbital structures — including the globe, optic nerve, extraocular muscles, and orbital walls — enabling the operator to confirm cannula placement within the intraconal space prior to anesthetic injection.[16,17] In a randomized controlled trial comparing ultrasound-guided versus conventional peribulbar block for cataract surgery, Vogt et al. demonstrated that direct visualization was particularly valuable for identifying vulnerable structures such as posterior staphylomas, which may be undetectable by external landmarks alone.[16] In the present series, the hypoechogenic signal (HS) observed upon anesthetic injection served as an objective, real-time surrogate marker of correct intraconal deposition, with an additional safety benefit: anterior globe displacement confirmed adequate anesthetic spread without requiring external ocular compression — a maneuver specifically contraindicated in open-globe surgery.[5]

Beyond safety, the continuous delivery modality of the Hyugoni® technique addresses a fundamental limitation of single-injection peribulbar blocks in penetrating keratoplasty: the unpredictability of block duration in the context of ocular inflammation. Corneal pathologies such as bullous keratopathy and infectious ulcers alter local tissue pH and increase vascular permeability, accelerating systemic absorption of local anesthetics and shortening block duration.[5] The median surgical time in this series was 100.6 minutes (IQR: 66–134), with cases extending up to 216 minutes — a duration that would routinely exceed the effective window of a standard single-injection peribulbar block.[5] The ability to administer controlled 1 mL supplemental boluses via the cannula intraoperatively, under direct ultrasound confirmation of positioning, allowed maintenance of surgical anesthesia without the hemodynamic risks associated with repeated needle punctures or increased anesthetic volumes delivered as a single bolus. In a review of local anesthesia practices for PK, Chua et al. highlighted the lack of standardized protocols for block maintenance during lengthy procedures, underscoring the clinical relevance of the approach described here.[5]

In the context of peribulbar block, the cannula does not need to exceed the axial length of the eye. Insertion via the caruncle has been associated with risks of injury to the medial rectus muscle and the angular artery;[14] the use of the Hyugoni® cannula under ultrasound guidance mitigated these risks by enabling direct visualization of intraconal structure movement and confirming precise anesthetic deposition. The addition of hyaluronidase facilitated uniform anesthetic dispersion, contributing to a low incidence of eyelid edema. Furthermore, the use of 1.0 mL syringes for intermittent intraoperative

supplementation allowed for slow, controlled drug administration, reducing intraocular pressure variability. The sterile nature of the entire assembly further contributed to minimizing the risk of surgical field contamination.

This study has several limitations that must be acknowledged. First, its retrospective, single-center design introduces selection and information bias, and limits the generalizability of findings to other institutions or patient populations. Second, the absence of a control group prevents causal inference or direct comparison of effectiveness with conventional peribulbar block or other anesthetic modalities. Third, although a postoperative pain questionnaire was administered as part of the original protocol, data collected beyond the immediate pre-discharge period were incomplete due to inconsistent capture across different evaluators, resulting in a sample of less than half the total cohort; to avoid introducing systematic bias from missing data, these results were excluded from the final analysis. Fourth, subjective outcomes such as patient anxiety and positional discomfort were not assessed using validated instruments. Finally, the technique was performed exclusively by experienced operators, which may limit reproducibility in settings with less ultrasound-guided regional anesthesia expertise.

Future prospective, randomized controlled trials comparing the Hyugoni® technique with conventional single-injection peribulbar block in penetrating keratoplasty are warranted to establish superiority, non-inferiority, or equivalence in terms of anesthetic efficacy, intraocular pressure dynamics, and patient-reported outcomes. Such studies should incorporate validated pain assessment instruments with systematic follow-up at 24 and 48 hours postoperatively.

4 CONCLUSÃO

Ultrasound-guided continuous peribulbar block with the Hyugoni® cannula demonstrated a favorable safety and effectiveness profile in this retrospective case series of PK patients, enabling surgical anesthesia with low total anesthetic volumes and minimal rescue requirements. The reproducibility of the described protocol and its potential applicability to other ophthalmic surgical settings warrant evaluation in prospective comparative studies.

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