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Application of trigonometric function to calculate the safe movement angle of cannula in 23G double-channel silicone oil removal

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三角函数法计算套管安全活动角度在 23G 双通道硅油取出术的应用

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摘要

目的:使用 UBM 在术前测量巩膜前表面到硅油泡的距离,利用三角函数的计算公式,从而计算出 23G 套管的安全活动角度,最大限度避免术中取油时损伤视网膜。

方法:从 2017/03-2017/09,共选取 15 例硅油眼患者,年龄32~69岁,首次手术均为视网膜脱离,左眼 10 例,右眼 5 例,均采用 23G 套管通过 23G 灌注管连接 5 mL 注射器,直接取油的方法。术前均通过 UBM 测量角膜缘后 4 mm,2:00 和 10:00 位的巩膜壁前表面到硅油泡的距离,定义为"A";23G 套管的长度为 4 mm,定义为"C";将巩膜套管最大活动角度时的巩膜内壁的宽度定义为"B";"A","B","C"构成直角三角形。利用三角函数计算出最大活动角度时"A"和"C"的正弦值,参考三角函数表得出 23G 套管的安全活动角度。根据此角度指导术中硅油取出时 23G 套管的活动范围,同时观察取油时间和穿刺口视网膜情况。

结果:所有患者均顺利取出硅油,所用时间平均为 4.78±0.13min。穿刺管口处视网膜未见任何新发视网膜裂孔和其他损伤。2:00 位巩膜壁前表面到硅油泡的距离为 0.82~2.81(1.62±0.41) mm, 10:00 位为 0.98~2.19 (1.71±0.34)mm,2:00 位巩膜套管的安全活动角度(指套管和巩膜壁的角度)不能低于 11~44(24.14±6.95)°,10:00 巩膜套管的安全活动角度不能低于14~33(25.45±5.41)°。模拟图形构建,计算穿刺套管安全活动角度为不低于 52°。

结论:利用三角函数的方法,结合 UBM 测量数据,计算套管安全活动角度可以有效的指导 23G 硅油取出术中套管针的活动范围,本研究建议套管移动角度不要低于 50°,可以最大限度的避免医源性裂孔的发生。

关键词:23G 双通道; 硅油取出; 安全运动角度; 三角函数

Abstract

• AIM: To explore the safe movement angle of a 23-gauge (G) cannula in double-channel silicone oil (SO) removal surgery.

• METHODS: From March 2017 to September 2017, 15 patients with SO filled eyes were enrolled in this retrospective analysis. Based on ultrasound biomicroscopy (UBM), the distance from the front surface of the sclera at the 2 o'clock and the 10 o'clock positions to the SO bubble at 4 mm behind the corneal limbus was measured and defined as "A". The length of the 23G cannula (4 mm) was defined as "C". The width of the scleral inner wall at the maximum operating angle of the scleral trocar was defined as "B". The safe movement angle of the 23G cannula was determined according to the trigonometric function table. Using the self-made SO removal device connected to the 23G puncture cannula, the SO was successfully removed from all patients.

• RESULTS: The average SO removal time for all patients was 4.78±0.13min. The trigonometric function was used to work out the distance from the scleral front surface to the SO bubble, which was 0.82-2.81(1.62±0.41)mm at the 2 o'clock position, and 0.98-2.19 (1.71±0.34)mm at the 10 o'clock position. Finally, the verification analysis using geometric model calculation showed that the optimal movement angle of the cannula was 52°.

• CONCLUSION: Combining the trigonometric function and UBM measurement to calculate the safe movement angle of a 23G cannula can effectively guide the moving range of the trocar during SO removal. A movement angle of the cannula larger than 50° may avoid the occurrence of a retinal tear.

• KEYWORDS:23G double-channel; silicone oil removal; safe movement angle; trigonometric function
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INTRODUCTION

Retinopathy is an ocular disease that damages the optical and neuronal integrity which can be caused by the build-up of pressure inside the eye[1-2]. Vitreoretinal surgery has been widely used in a lot of types of retinopathy, such as vitreous loss, giant retinal tears, diabetic retinopathy, *etc*. In 1962, Cibis *et al*[3] first used silicone oil (SO) as an intraocular tamponade in retinal detachment with proliferative vitreoretinopathy. SOs are hydrophobic compounds composed of bonds between silicone and oxygen. This chemical structure makes SO an insert compound, which has some advantages for intraocular use since it can remain *in situ* for an extended period of time[4]. Currently, SO has been routinely used in vitreoretinal surgery[5]. However, a number of complications, including cataract, glaucoma and keratopathy, can occur if the emulsified SO is not removed in time[6]. Hence, removal of SO is recommended as soon as a stable situation in the retina has been achieved in order to reduce the risk of anterior segment complications[7].

In the clinical setting, there are different techniques for SO removal, such as the use of 20-gauge (G) and 23G cannulae with double-channel or three-channel technique[8-9]. Because the flow resistance of SO increases with reduction of the inner diameter of the extrusion cannula, 23G is more suitable for SO extraction in vitreoretinal surgery[10]. Yan *et al*[11] have shown a safe and effective SO removal surgery by a three-channel 23G sutureless incision. A comparison between a modified 23G cannula with suturing incision and traditional 20G vitrectomy for SO removal revealed that the former is better in terms of safety and efficacy[12]. Although the double-channel 23G incision has the characteristics of high negative pressure and high speed, it is difficult to observe the orifice of the double-channel cannula, and the width of the remaining vitreous skirt is different in each patient[13]. Furthermore, during the surgical procedure, with the decrease of SO in the vitreous cavity, it is necessary to adjust the direction of the 23G cannula to remove the final oil droplets. However, during this process, due to the presence of residual vitreous skirt in the puncture site, it is possible to damage the retina by inadvertently imbibing the vitreous body. Therefore, the establishment of the safe movement angle of the 23G cannula might avoid retinal damage during the operation.

A total of 15 patients with SO tamponade were enrolled in the present study, which was a retrospective analysis. The distance from the front surface of sclera to the SO bubble was measured by ultrasound biomicroscopy (UBM) before surgery. Meanwhile, the triangular function formula was used to calculate the safe movement angle of 23G cannula. We anticipated minimization of the retinal damage during oil extraction using the optimal movement angle of the 23G cannula that we planned to determine.

SUBJECTS AND METHODS

Clinical Data From March 2017 to September 2017, a total of 15 patients (average age: 53.53±10.48 years) with SO filled eyes following retinal detachment surgery were enrolled in the present retrospective analysis. The filling duration of SO was 3-6mo, with an average of 4.33±1.23mo. These patients consisted of 6 men and 9 women, with 10 left eyes and 5 right eyes. Additionally, 3 cases were combined with cataractomy (phacoemulsification), two of whom underwent primary intraocular lens implantation. No obvious retinal detachment was observed in any of the patients during the dilated-pupil retinal examination. Informed consent forms were signed by all enrolled patients as required by the Helsinki Declaration. This study was approved by the Ethics Committee of the First Affiliated Hospital of the University of Science and Technology of China (Anhui Provincial Hospital).

Ultrasound Biomicroscopy Detection Before Surgery The patient was placed in a supine position. In order to anesthetize the conjunctival surface, 0.5% ropivacaine hydrochloride eye drops (Alcon, USA) were instilled. An eye cup that matched the examining eye was selected and placed in the conjunctival sac, with 0.9% normal saline as the examination medium. The distance from the front surface of the sclera at the 2 o'clock and 10 o'clock positions to the SO bubble at 4 mm behind the corneal limbus was measured using UBM (MD-300L, MEDA Co., Ltd).

Calculation of Moving Range of Trocar Based on Trigonometric Function Based on preoperative UBM detection, the distance between the front surface of the sclera at the 2 o'clock and the 10 o'clock positions, respectively, to the SO bubble at 4 mm behind the corneal limbus was measured and defined as "A". The length of the 23G cannula (4 mm) was defined as "C". The width of the scleral inner wall at the maximum operating angle of the scleral trocar was defined as "B" ("A", "B", and "C" formed a right-angled triangle). After this, the sinusoidal values of "A" and "C" were calculated using a trigonometric function, and the safe movement angle (the angle between trocar and scleral wall) of the 23G cannula was calculated according to the trigonometric function table. Finally, the activity range of the 23G cannula during the SO removal surgery was achieved (Figure 1).

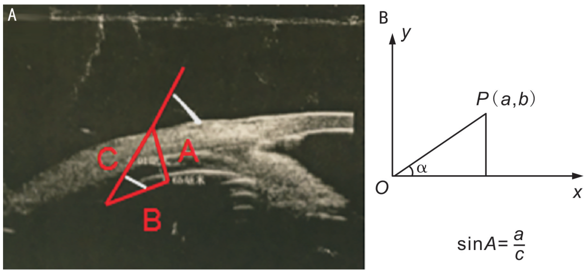


Figure 1 The optimal movement range ofcannula calculated through trigonometric function during the silicon oil removal
A: Preoperative ultrasound biomicroscopy detection. "A" represents the distance between scleral front surface and silicone oil bubble at 2 o'clock and 10 o'clock position of 4 mm behind limbus cornea; "B" represents the width of the scleral inner wall at the maximum movement angle of cannula; "C" represents the length of 23G cannula (4 mm). B: The schematic diagram of trigonometric function calculation in current study.

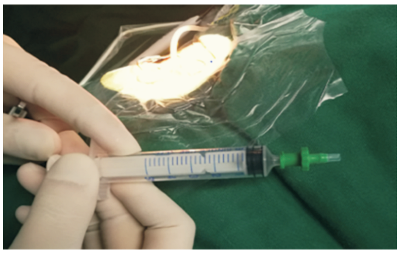


Figure 2 A self-made silicon oil removal device 23G perfusion tube was connected to the 10 mL syringe.

In addition, since the human eye is a spherical object in anatomical morphology, a geometric model that approximated to a sphere was constructed to further verify the above plan-based results.

Operative Procedure The patient was subjected to retrobulbar anesthesia with a 50% mixture of 2% lidocaine and 0.75% bupivacaine. Povidone iodine and saline were used to rinse the conjunctival sac. A 23G trocar was inserted into a 4 mm span of posterior corneal limbus beneath the temple and a perfusion tube was inserted (trocar puncture at the 10 o'clock position). A self-made 23G perfusion tube was connected to a 10 mL syringe (Figure 2) and then the 23G cannula was connected.

The SO was extracted by the syringe under negative pressure. In the process of oil extraction, the trocar was moved according to the direction of the SO bubble in the vitreous cavity. The moving range of the cannula was controlled according to the safe movement angle calculated from the trigonometric function. At the end of oil extraction, the retinal fundus was observed with an optical fiber ophthalmoscope, and finally gas-liquid exchange was conducted under microscope illumination and corneal contact lens to replace the remaining emulsified oil droplets. The puncture site was sutured with 8-0 absorbable suture material.

Statistical Analysis Statistical analysis was performed using Statistical Package for the Social Sciences (version 17.0; SPSS Inc., Chicago, IL, USA). All data were expressed as mean±SD. The comparison of the distance and the angle between the anterior surface of the scleral wall and the SO vesicle was conducted using independent t-test. P value less than 0.05 was considered to be statistically significant.

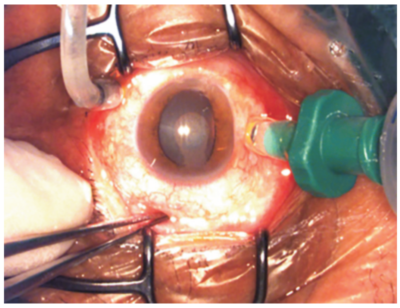


Figure 3 The device for double-channel silicon oil removal in current study.

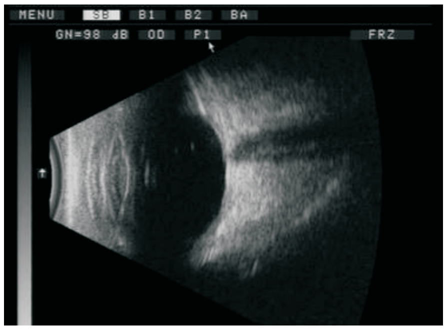


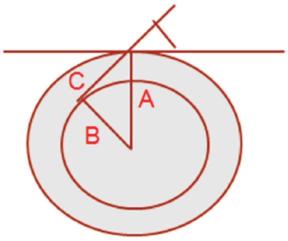
Figure 4 B-mode scan results showed no significant SO remnant was observed during the patient follow-up.

RESULTS

Silicone Oil Removal Time Based on the self-made SO removal device connected to a 23G puncture cannula, the SO was successfully removed from all patients with the double-channel removal method (Figure 3). The time taken for removal of SO was 4.78±0.13min. No retinal detachment was found at the end of the operation and no retinal injury was detected at the puncture site. No retinal detachment occurred during the follow-up period of 2mo. B-mode echography showed no significant SO remnant was observed during outpatient follow-up (Figure 4).

Distance from the Front Surface of Sclera to the Silicone Oil Bubble According to the result of UBM examination, the distance from the scleral front surface to the SO bubble was 0.82-2.81 (1.62±0.41) mm at the 2 o'clock position, and 0.98-2.19 (1.71±0.34) mm at the 10 o'clock position. There was no statistical difference between the two groups (P>0.05).

Safe Activity Angle of Puncture Cannula The distance from the front surface of the scleral wall to the SO bubble was defined as the length of side A, and the length of side C was 4 mm. Based on the trigonometric function measurements, the safe activity angle of the scleral cannula at the 2 o'clock position (the angle between the cannula and the scleral wall) should not be less than 11-44 (24.14±6.95)°. Meanwhile, the safe activity angle of the scleral cannula at the 10 o'clock position should not be less than 14-33 (25.45±5.41)°. There was no statistical difference between the two groups (P>0.05).



$$\cos A = \frac{b^2 + c^2 - a^2}{2bc}$$
$$\cos B = \frac{c^2 + a^2 - b^2}{2ca}$$
$$\cos C = \frac{a^2 + b^2 - c^2}{2ab}$$

Figure 5　Verification of safe movement angle of cannula based on geometry model　"A" represents the eyeball radius (12 mm); "C" represents the cannula length (4 mm). "B" represents the difference between eyeball radius and the distance from scleral wall to silicone oil surface.

Safe Activity Angle of Puncture Cannula Based on Geometric Model　The geometric model was constructed. As shown in Figure 5, "A" represents the eyeball radius (12 mm); "C" represents the length of cannula (4 mm); "B" indicates the difference between the eyeball radius and the distance from scleral wall to SO surface (the maximum value was 2.81 mm). By substituting the maximum value of 2.81 mm into the formula, the maximum activity angle of cannula could be obtained under the assumption that the eyeball was absolutely circular. According to the cosine function table, the angle B was 38°. Therefore, the angle of cannula movement was 52° (90°−38°=52°).

DISCUSSION

Although SO removal after complex retinal detachment surgery is an essential procedure, it is necessary to improve the safety and accuracy of this operation[14]. In this study, 23G double-channel SO removal was performed in patients using a self-made SO removal device, and preoperative measurement data were used to guide the movement range of the cannula during the operation. The results showed that the maximum width of the vitreous skirt at the puncture site detected by UBM was 2. 81 mm. Finally, based on the trigonometric function, the optimal activity angle of cannula should not be less than 50°.

SO is widely used in vitreoretinal surgery, which provides long-term tamponade in cases of complicated retinal detachment. It is should be removed after three months or more if the retina remains attached[15]. Hitherto, many safe and effective techniques have been performed for SO removal in clinical ophthalmology, including 23G and 25G three-channel or double-channel SO removal operations[16-17]. One study showed a passive 23G SO remomal system is a safe and efficient surgical technique for SO removal[18]. Hou *et al*[19] indicated that the operation of 23G SO removal *via* a self-made disposable transfusion set was safe, effective and economical. However, the residual vitreoretinal traction especially at the vitreous skirt is a major reason for retinal reattachment after SO removal[20]. One previous study shown that residual vitreous is one of the leading causes of retinal redetachment after SO removal surgery[21]. However, the width of residual vitreous skirt near the puncture site is not easily determined. In this study, the distance between the scleral wall and the SO surface was firstly measured by UBM to be 4 mm behind the corneal limbus. The result showed that the distance from the scleral front surface to the SO bubble was 0.82−2.81 (1.62±0.41) mm at the 2 o'clock position, and 0.98−2.19 (1.71±0.34) mm at the 10 o'clock position. Besides, there was no significant difference between the two groups. However, the vitreous residue is related to the surgical method adopted, and so may vary greatly between different surgical teams.

In the 23G or 25G dual-channel silicone oil removal process, as the SO bubbles decrease in size and number, it is often necessary to move the cannula so that the final SO droplets are always at the casing nozzle, and the SO is fully removed without leaving any residue.

During the operation of SO removal, the cannula should be moved in line with the reduction of the SO bubble in order to keep the SO droplets in the cannula nozzle, which may reduce the risk of SO residue[21]. Moreover, during cannula movement process, the residual vitreous body may be mistakenly sucked or pulled, which may indirectly lead to retinal tear and may progress to retinal detachment[20-22]. Hence, an investigation into the range of safe movement of the cannula on the surface of the eye in surgical removal of SO is an important step to take. In this study, after measuring the residual thickness of vitreous body, the safe angle between the cannula and sclera wall was calculated indirectly by using a trigonometric function, namely a simple cosine formula. Combined with the data of safe activity angle of the scleral cannula at the 2 o'clock and the 10 o'clock positions, the results showed that the moving angle of the cannula should be greater than 44°. It has been reported that the image analysis procedures and numerical calculation systems are used to realize a computer model for clinical surgery[23]. Actually, the geometric model has been widely used in clinical ophthalmic surgery[24-25]. Matsumiya and Kaneko[26] have also shown that a numerical model construction could assist in certain surgical procedures on the eye. The present study extended this principle to compute the movement angle of the cannula to the case of a spherical object. The result revealed that the optimal movement angle was 52°. Since the scleral wall of the eyeball is neither straight nor circular, we speculated that during 23G double-channel SO removal surgery, the risk of occurrence of retinal hiatus might be reduced by the greatest margin when the cannula movement angle is greater than 50°.

However, there were some limitations in this study such as small sample size, lack of comparison about the 23G and 25G SO removal system. To the best of our knowledge, 25G transconjunctival sutureless vitrectomy system (TSVS) has been widely applied today, Kapran *et al*[27] reported removal of silicone oil of 1,000 centistokes with 25G transconjunctival sutureless sclerotomies was effective and safe. Another study compared the 20G and 25G system in 5,000 centistokes silicone oil removal surgery. The results showed 25G silicone oil removal system is safe and effective. The mean time of SO removing is 20±8min. Surgical time is significantly reduced using sutureless 25G sclerotomies[28]. As far as we know, 25G transconjunctival sutureless systems would take longer time to remove SO as the diameter of the instruments is small[29]. So 23G silicone oil removal system still can be considered another method. One study showed a machine-independent method of having active removal of 5,000 centistokes silicone oil using 23G microcannulas[30]. The mean time for draining out the silicone oil was 4.54±0.78min. In our study, we used a similar modified 23G SO removal device and the mean SO (5,000 centistokes) removal time was 4.78±0.13min. Our results were consistent with the former study. Thus, 23G and 25G SO removal systems are both safe and effective methods. The machine-independent 23G device in this study may take a shorter time in SO removal surgery, especially for 5,000 centistokes SO. But our study is limited by its small sample size, and a further study based on a larger sample size is needed.

In conclusion, 23G double-channel SO removal is a safe and effective surgical technique. Moreover, preoperative measurement of thickness of residual vitreous by UBM can guide the movement angle of the cannula intraoperatively to avoid the occurrence of retinal tear.

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最新中国科技核心期刊眼科学类期刊主要指标及排名

刊名	核心总被引频次		核心影响因子		综合评价总分	
	数值	排名	数值	排名	数值	排名
中华眼科杂志	2040(3435)	2(2)	0.953(1.073)	1(4)	78.4	1
眼科新进展	1273(545)	3(4)	0.690(1.344)	4(3)	60.5	2
国际眼科杂志	**2446(5519)**	**1(1)**	**0.667(1.412)**	**5(2)**	**57.2**	**3**
中华眼底病杂志	865	5	0.878	2	54.3	4
中华实验眼科杂志	1018	4	0.692	3	46.2	5
临床眼科杂志	513	7	0.523	6	38.5	6
眼科	387	8	0.398	8	27.1	7
中华眼视光与视觉科学杂志	528	6	0.390	9	25.5	8
中国斜视与小儿眼科杂志	256	9	0.470	7	10.1	9
9 种期刊平均值	1036		0.629			

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