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## Invited Review

## Development of medical treatment for eye injuries in the mainland of China over the past decade

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## ABSTRACT

In the article, the development of medical treatment for eye injuries in the mainland of China was reviewed. According to the data provided in Eye Injury Vitrectomy Study (EIVS), 27% of 72 eyes with no light perception (NLP) gained recovery in term of anatomy and visual function. Vitrectomy initiated at more than 4 weeks after open eye injury is an independent risk factor for developing PVR. Prognosis of anatomy and visual function of the injured eye with PVR is markedly worse than that without PVR. Serious injuries of ciliary body, choroid and retina are three key parts of the eye with NLP. The concept that the treatment of the eye injury gradually focus on the whole globe is embodied. The data from 13575 in patients with traumatic eyes in 14 hospitals revealed that the rate of immediate enucleation was remarkable reduced with comparison of 20 years ago.

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Ten years ago, we made a general review of the development of medical treatment for eye injuries in the mainland of China.<sup>1</sup> Five years ago, we focused on elaboration on the important progress in the timing of vitrectomy for the injured eyes,<sup>2</sup> the continuous treatment for open anterior segment injury and the treatment for the severely injured eye with no light perception (NLP) in the mainland of China.<sup>3</sup> Although a decade has passed, the public health problem related to eye injuries is still serious. Therefore, ocular traumatology group is still maintained now to satisfy the actual need for the division and framework of ophthalmology field. Besides, attributed to the work of ophthalmologists, China has made a greater improvement mainly in the following aspects compared to other countries:

### Further development of theory and practice in the treatment for the severely injured eye

#### 1. Eye Injury Vitrectomy Study (EIVS)

According to the evidence-based data provided in EIVS, 27.8% of 72 eyes with NLP gained recovery in term of anatomy and visual

function. In other words, in every four severely injured eyes which should have been enucleated, one can be saved, which reveals the capability of modern clinical ophthalmic treatment for the severely injured eye, and is a symbolic indicator for the reachable height of rescue in comparison with the previous one.

When investigating the outcome of the remaining injured eyes other than those being successfully saved, we will find that the significance is not limited to the above. Of 72 eyes, silicone oil-sustained eyeball accounted for 52.8% (38 eyes), 4 atrophic bulbi and 1 ocular hypotension.<sup>4</sup> This is similar to the malignant tumor in other organs in that prognosis and remaining life vary with different pathological subtypes. The prognosis of the severely injured eyes should be different, which has been confirmed by the facts. There must be an intermediate state. Hardly does a clear distinction between two things exist in the nature. The continuous transition among the prognosis of eyes in danger with series of scales reflects the nature of the disease, which change our traditional view and routine in management of the severely injured eyes in clinics, force people to abandon the mechanical classical way of thinking when making clinical decision, such as the way of relying on certain standards to decide whether to enucleate the eyeball, and make people understand that transition is present not only among the prognosis of a disease, but also among living manners after they underwent a fatal disaster. Although living with the silicone oil-sustained eye is not as good as that with the healthy eye, it is better than that without the eyeball. Even if globe atrophy occurs 10 years later, there is a great

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difference in the quality of life when compared with immediate loss of the injured globe.

## 2. What happened in the eyes with NLP?

For the severely injured eyes, intraocular tissue injuries will be various with unbalanced severity distribution. However, it is unknown which tissue injuries are critical and which degree of injuries can cause lethal damage to the globe, as the great individual difference among the injured eyes makes it difficult to draw a general rule according to ophthalmologists' personal practice. The results of multicenter controlled study reveal the secret that has been present for a long period of time: a) The ciliary body, choroid and retina are three key parts of the eye with NLP, and serious eye injury may be concurrently involved with the injury of the three tissues or mainly involved with one or two tissues<sup>4,5</sup>; b) The three key tissues, if seriously damaged, are characterized by the injury of ciliary body tissues (such as extensively damaged ciliary process, epithelial exfoliation and extensive centripetal ciliary body detachment), the severely injured choroid (such as tearing, expulsive suprachoroidal hemorrhage and retinal pigment epithelium exfoliation), and the closed funnel-shaped retinal detachment.

## 3. Key problems to be tackled in the treatment for the severely injured eye

It can be known from the main lesions in the eyes with NLP that high risk factor is severe injury of the ciliary body, retina and choroid. Therefore, core problems in the treatment can be confirmed, among which some are classical while the others are yet to be tackled. Repair of retinal injury is just a typical problem. For example, the continuous practice in treatment for the injured eyes makes ophthalmologists realize that an isolation strip should be created between the wound site and the relatively normal retina surrounding the wound. Foreign ophthalmologists often remove the retina together with the choroid, while Chinese ophthalmologists only remove the retina, which is known as "firewall" technology and has been considered as effective. However, the prevention and treatment of traumatic proliferative vitreo-retinopathy (PVR) is an old but novel topic, for which none of essential breakthrough but certain progress<sup>6,7</sup> has been made in resolving some problems. It may be necessary to wait for significant breakthrough in the realization of the nature of life and the disease, such as the transformation after combining the wound-related electric field and contact inhibition<sup>8</sup> with the clinical concept.

Matured surgical technology for the repair of serious choroid injury among globe rupture, particularly the large choroidal tear combined with expulsive hemorrhage, in contrast with the retina, is still absent, which becomes a key problem to be tackled in future treatment for the injured eyes. Although minor tear or hole in the choroid can be repaired via scleral buckling,<sup>9</sup> trans-scleral suturing<sup>10,11</sup> and gluing with biogel, effective technology still needs to be developed for the treatment for extensive choroidal tear with cleft edge reaching the midline and the posterior choroidal tear caused by fireworks in recent years.

Extensive ciliary body injury is common in the injured eyes with NLP, particularly those caused by a globe rupture, which is an independent risk factor statistically,<sup>4,5</sup> also a key problem to be tackled in the future treatment for the injured eyes. Extensive ciliary body injury herein means that the ciliary body is detached by more than half ring, making the ciliary ring become D-shaped, or even the detached ciliary body is folded over and covers the

area on the opposite side; besides, ciliary body parenchyma is also damaged seriously, such as absence of the ciliary process, exfoliation of ciliary epithelium (including non-pigmented epithelium and pigment epithelium) exposing white fiber-like parenchyma, and ciliary body tissue decay caused by contusion. In case of serious PVR at the anterior segment caused by a blast injury, it can be seen that the whole ciliary ring is pulled toward the center to form a "purse opening". For the above-mentioned lesions, even though reposition can be achieved by trans-scleral suturing and fixation, it is difficult to save the seriously injured ciliary body.

Even so, it is scientifically significant to repair local eye tissue which looks devitalized and difficult to recover, for the following two reasons: a) The repair of single tissue may be more significant in restoration of globe integrity, as the final outcome of the globe depends on the overall recovery of globe tissues and the potential for the recovery of local tissue cannot be determined by general observation; b) The concept that the treatment of the eye injury gradually focuses on the whole globe is embodied. It is also an inevitable trend towards the treatment of the ciliary body after a great progress has been achieved in the treatment of anterior and posterior segment injuries.

## Significant progress in the clinical treatment for traumatic PVR

Among the controversies with regards to the management of open eye injury, timing of vitrectomy has not been resolved yet, which is directly related to such a common clinical problem. Therefore, proper time window of vitrectomy for open eye injury has not been determined up to now, which directly affects the development of routine clinical protocol. The main barrier to the resolution of this problem is that allowable maximum delay in performing vitrectomy which will not lead to poorer prognosis was unknown, because the surgery cannot, in violation of ethical principles, be delayed to observe throughout complete time in clinical studies. The immediate cause for poor prognosis of open eye injury is traumatic PVR, which is confirmed by the previous studies. Besides, such conclusion is basically consistent with actual clinical condition. After suffering the injury, it takes some time for PVR to develop. Thus the close correlation between PVR and post-injury duration is just involved with the relationship between the time of surgery and the prognosis, which is a key problem resolved in EIVS. First of all, there is enough frequency (number of patients) to meet statistical analysis requirement from the aspect of interval from injury to surgery (post injury one week to three months in EIVS database), which makes it possible to make clear the above-mentioned allowable maximum delay in performing surgery. Meanwhile, the information about patients treated as the control group is provided in the database. Only homogeneous control group meets the need for the investigation of the impact of PVR on the prognosis of anatomy and visual function. Two important conclusions are reached in EIVS: a) Vitrectomy initiated at more than 4 weeks after open eye injury is an independent risk factor for developing PVR; b) For homogeneous injuries, the prognosis of anatomy and visual function of the injured eye with PVR is markedly worse than that without PVR. Therefore, based on the EIVS data, it is concluded that the time of performing vitrectomy for open eye injury should not be later than 4 weeks post injury, otherwise, the risk for PVR, if complicated by retinal detachment, will significantly increase. In simple clinical terms, the time of performing surgery directly influences the prognosis of the opening-injured eye.

## Comprehensive development of medical treatment for eye injuries in China

In the development of medical treatment for eye injuries in China in recent years, it is exciting that scientific practices have become more and more liberal and democratic for a long-term stable and peaceful environment, and thus the clinical scientific and basic theoretic researches of eye injuries are no longer limited by a narrow vision and gradually develop in an extensive and in-depth way.

1. Injury mechanism research. The research on optic nerve injury mechanism<sup>12</sup> and neuroprotection<sup>13</sup> has expanded from regeneration mechanism to immune and inflammatory mechanism<sup>14</sup> and focuses on the correlation between brain injury mechanism and optic nerve injury mechanism.<sup>15,16</sup>
2. So far, as indispensable retina tamponade used in vitrectomy, silicone oil and long-acting gas are irreplaceable. However, their defects and relevant complications are obvious. Better filler has long been expected to replace existing materials clinically.

Foldable capsular vitreous body<sup>17,18</sup> independently developed by Zhongshan Ophthalmic Center reflects such an innovative awareness. Of course, whether it can be universally and clinically applicable and even replace silicone oil and long-acting gas depends on constant improvement and long-term clinical verification.

3. Postoperative endophthalmitis, particularly endophthalmitis after cataract surgery, has been well realized and can be successfully managed. The pathogenic microbiology and the established clinical protocol for infectious endophthalmitis post trauma are still weak worldwide. A large-scale retrospective study has provided the important information and reference for pathogenic microorganism and drug sensitivity in the treatment of post-traumatic endophthalmitis.<sup>19</sup>
4. Contusive macular hole. A multicenter study has been completed under the guidance of the ocular traumatology group. Although the study report has just been accepted for publication, its conclusion will change people's impression from sporadic clinical reports and make them know that post-traumatic macular hole is very likely to close automatically. The persuasive contents of the study will make surgeons no longer confused whether to actively perform surgery or follow-up observations for post-traumatic macular hole.
5. Application of minimally invasive surgery in pediatric eye injuries. A significant difference is shown in the prognosis of the injury and surgical trauma between pediatric eyes in developmental stage and adult eyes. A consensus has been gradually reached that the surgery should be simple, take a short time and reduce further damage. The concept put forward by the Department of Trauma Surgery of Beijing Tongren Hospital and the Department of Ophthalmology of Shanghai Xinhua Hospital in various academic exchange occasions has been widely accepted.
6. Epidemiological research on eye injuries. According to the demography-based epidemiological report of the Handan Eye Study,<sup>20</sup> the blindness rate of eye injury was 6.1%. Except for the mixed diseases including corneal opacity (9.9%) and other maculopathies (7.3%), among single diseases, the ocular trauma ranks after cataract, amblyopia and myopic maculopathy in the blindness rate, tied with glaucoma for fourth. Considering the curability rate (31.0%) of blindness in cataract and the residual vision of amblyopia, ocular trauma appears more critical in term of blindness. In addition, the overall impact of ocular trauma is

greater. For example, its cosmetic appearance is poorer compared to amblyopia. Both eyes are usually involved after a blast injury, which has more extensive effect on society and economy.

The data about the inpatients with traumatic eyes in 14 hospitals were listed in Table 1. The results of these retrospective studies separately completed by Chinese researchers were various. However, there were some similar contents of the basic information provided in these reports. We extracted these contents from them as the data in the table. Some important information was not in all the studies involved, such as the rate of enucleation, endophthalmitis, the bilateral eye injuries and the absence of light perception which are recalculated. Although individual items were not complete, some interesting and meaningful information can be obtained when we analyzed these studies together.

First of all, the data obtained in recent years have practical significance. The source of information was from hospitals at and above county level including eye specialist hospitals and tertiary referral hospitals, which are located in the regions at different levels of development, and thus the data are representative. A total of 13,575 cases were enrolled. In contrast with those with other eye diseases, most patients with eye injuries have to receive emergency treatment in the nearest hospital; therefore patients' migration is not high. Basically, these studies' results can reflect the general situation of eye injury in the corresponding regions. Minor eye injuries and illnesses which could be treated in the outpatient department were excluded and only inpatients were investigated in all studies; thus the data are basically consistent in disease severity.

In the above 14 reports, except for Tongji Hospital (tertiary referral hospital), Xiamen Eye Center (specialist hospital) and Taizhou Municipal Hospital in Zhejiang Province, eye injuries accounted for 1/5–1/3 of eye diseases in other 9 hospitals in the same period, more than 1/3 in 3 hospitals, and not less than 1/5 even in Hebei Sheng Eye Hospital. Based on the data, these studies show the proportion and the importance degree of eye injuries in the eye hospitals and medical institutions at all levels. The data in the study of Xu and Wang<sup>35</sup> have been re-sorted out by us. Excluding the hospitals listed in Table 1, the records of other 21 hospitals show that eye injuries accounted for 16.0%–19.9% (<1/5) of eye diseases in 5 hospitals in the same period, 20.0%–24.9% (1/5–1/4) in 7 hospitals, 25.0%–33.3% (1/4–1/3) in 6 hospitals and 33.4%–58.5% (>1/3) in 3 hospitals. The proportion of the treatment of eye injuries in all medical tasks in the department of ophthalmology can be made clear. Meanwhile, the task and challenge in the prevention and treatment of eye injuries that we will face are pointed out.

Two peaks of incidence of eye injury can be found: the children (<15 years old) and young adults (16–50 years old). The high incidence of pediatric eye injuries makes us have a clear understanding of the poor precaution and public awareness. According to the reports from Zhaoqing City, Guangdong Province and Nanyang City, Henan Province, the ratio of the eye injuries in rural children to those in urban children was about 3.5:1 and 3:1.<sup>36,37</sup> Obviously, the problem in rural children is more serious and difficult to prevent. The First Hospital of Tianshui in Gansu Province reported that 6 pediatric eyes were injured by a disposable injector, 5 of which had endophthalmitis,<sup>28</sup> indicating that the prevention of eye injuries is involved with all aspects of the society.

Accidental injuries of the young adults who are main working-age population will bring dual burdens to the society. On one hand, they cannot create value for the society; on the other hand, they consume medical resources. With the rapid urbanization in China, the eye injuries in off-farm workers have become noticeable. In 1022 cases of Wang's study,<sup>33</sup> the eye injuries in off-farm

**Table 1**  
Data of inpatients with ocular trauma in 14 hospitals.

Author	Year	Source of information	Cases (n)	Proportion in all inpatients (%)	Children (%)	Young adults (%)	NLP (%)	Rate of enucleation (%)	Infectious endophthalmitis (%)	Bilateral eye injury (%)	Special description
Qu LY, et al <sup>21</sup>	1994–1998	Huainan Institute of Technology, Anhui Province	384	22.8	26.8	51.0	–	6.5	4.7	6.25	
Fan YM, et al <sup>22</sup>	1996–1997	Hebei Sheng Eye Hospital	2786	20.4	32.9	65.1	–	1.7	1.1	13.0	
Dai HM <sup>23</sup>	1993–2001	The First Hospital of Kunming	498	23.0	13.7	84.5	3.0	1.6	–	8.2	
Zhang H, Wang JM <sup>24</sup>	1996–2000	Tongji Hospital, Wuhan, Hubei Province	726	15.5	36.5	61.4	9.2	2.8	1.4	2.8	
Huang B <sup>25</sup>	1996–2000	Longgang District Central Hospital of Shenzhen	619	52.5	15.3	84.5	35.5	–	–	6.3	
Li X, et al <sup>26</sup>	1999–2001	Xiamen Eye Center of Xiamen University	741	16.4	15.9	77.3	9.0	–	3.0	10.8	
Li GX et al <sup>27</sup>	1992–1998	Dali Bai Autonomous Prefecture People's Hospital, Yunnan Province	240	21.4	20.4	70.4	9.2	7.9	–	–	
Wang KC, et al <sup>28</sup>	1980–2000	The First Hospital of Tianshui, Gansu Province	986	39.3	39.2	54.9	–	–	4.0	1.1	6 eyes were injured by a disposable injector, 5 of which had endophthalmitis
Zhang Z, et al <sup>29</sup>	2000–2002	Ezhou Central Hospital, Hubei Province	597	34.7	19.4	72.2	7.5	2.7	–	–	
Lu XL, et al <sup>30</sup>	1992–2002	Taihe Hospital, Hubei Province	769	23.6	28.3	65.9	9.8	7.2	3.0	5.0	
Yan LJ, et al <sup>31</sup>	2001–2005	The First Affiliated Hospital of Harbin Medical University	1672	–	15.0	65.4	–	–	–	–	Injury type, visit time
Gong Y <sup>32</sup>	1983–2006	The Hospital of Tu and Miao Autonomous County, Chongqing	1452	–	35.5	58.7	9.0	2.8	–	–	Intraocular foreign body (67.6%), blast injury (10.6%)
Wang CJ, et al <sup>33</sup>	2006–2011	Taizhou Municipal Hospital, Zhejiang Province	1022	14.7	8.9	73.5	–	–	1.57 <sup>a</sup>	–	Off-farm workers (67.7%), work-related injury (71.6%), Intraocular foreign body (56.4%)
Che HX, et al <sup>34</sup>	2005–2009	Jinzhou Central Hospital, Liaoning Province	1083	26.7	–	–	–	–	–	–	

<sup>a</sup> 50% infectious endophthalmitis was induced by intraocular foreign body.

workers accounted for 66.7%, the industrial injuries 71.6% and intraocular foreign bodies 56.4%, which are astonishingly high. In the three groups of eye injuries reported by Wu, Zhang and Gong, intraocular foreign bodies accounted for 45.3%, 54.8% and 67.6% respectively.<sup>35</sup> The consensus has been reached that intraocular foreign body is an important risk factor for developing infectious endophthalmitis.<sup>38</sup> Zhang et al<sup>39</sup> reported that the incidence of endophthalmitis was 16.76% in 1421 cases of intraocular foreign bodies in 15 tertiary referral hospitals in China. Because there is a large population of off-farm workers, which has been up to 0.24 billion according to 2011 report issued by the National Bureau of Statistics, it is urgent to increase their awareness of safety and provide legal support for the pre-employment training.

According to the data of the 8 hospitals listed in the table and the 16 hospitals mentioned in the study of Xu, the rate of enucleation was 1.5%–3.9% in 7 hospitals, 4.0%–6.9% in 11 hospitals, 7.0%–9.9% in 4 hospitals and 10%–13.3% in 2 hospitals, where the rate of enucleation was less than 10% in 22 hospitals, which accounted for 91.7%, and the rate was more than 10% in 2 hospitals only, respectively located at Lhasa City, Tibet and Zhalantun City, Inner Mongolia. The above-mentioned data indicate that qualitative progress has been made, compared to the rate of enucleation (10%) in 1568 cases reported by Chinese Journal of Ocular Trauma and Occupational Eye Disease 20 years ago,<sup>40,41</sup> and 18.6% of 520 cases reported by Wu<sup>42</sup> in 1991. The rate in the inpatients was as high as 9.1% even in Zhongshan Ophthalmic Center from 1965 to 1978.<sup>43</sup> In order to understand the situation in China more clearly, the rates in other countries are provided. It was 10.1% in 118 cases of open eye injuries in southern Israel from 1996 to 2005.<sup>44</sup> According to the 2001–2010 report by the Trauma Center, at University Hospital, Newark, New Jersey, 6.0% of 183 work-related injured eyes underwent enucleation,<sup>45</sup> and 45.9% of 148 assault-related injured eyes with NLP and 31.1% received enucleation.<sup>46</sup> According to the 2001–2012 report of the Trauma Center in Queens, New York, there were 441 cases of eye injuries, with the enucleation rate of 5.0%.<sup>47</sup> By comparing with the high rate in the Trauma Center, University Hospital, we can find that China has made remarkable achievement in the education and medical treatment for eye injuries in recent years.

About the rate of infectious endophthalmitis, the lowest was 1.1% and the highest 4.7% in 7 hospitals in the table. There were 7414 cases in the above-mentioned hospitals totally. The incidence was obviously lower than 13.1% reported by Chinese Journal of Ocular Trauma and Occupational Eye Disease.<sup>41</sup> According to the report by the First Affiliated Hospital of Harbin Medical University, among 1672 patients with eye injuries, 1198 visited the hospital within 24 h after the injury, accounting for 71.7%,<sup>31</sup> while the proportion was 81.1% in the Trauma Center, University Hospital, Newark.<sup>48</sup> The decrease in the incidence of infectious endophthalmitis reflects the progress in overall medical aid and comprehensive society safeguard in China.

Eyes with NLP after injury are an important sign that reflects the severity of the injury. Of the 14 hospitals in the table, 8 provided data related to the rate of eye with NLP, including 6 with rate ranging from 7.5% to 9.8% and the remaining two 3.0% and 35.5% respectively, showing a significant dispersion degree. Because of patients' strong psychological hint within a short term after the injuries, correct results cannot be obtained from repeated vision examinations unless the effect of psychological hint is excluded. Based on the statistic data provided in these articles, during clinical routine activities, attention has not been sufficiently paid to light perception, an important index for the judgment of injured eyes prognosis.

These reports provide valuable data while show explicit statistical inconsistency, and thus gives related academic organizations

an urgent task: to provide a recommended plan for statistical items. In addition, follow-up results of the studies are clearly absent in these reports, causing a loss of more than 50% to the original value of these data sources, which are expected to develop into world-class ones if these cases are consummated to a database with follow-up results.

## Conclusion

In the past five years, cognition of prognostic law of the severely injured eyes, closer to the essence, has significantly changed the concept of treatment and pushed the development of routine clinical protocol. The primary revelation of main pathological changes inside the eyes with NLP helps to clarify the key points in the treatment of severely injured eye, and shifts technique focuses of injured eye treatment towards ciliary body and choroid. Clinical studies of injured PVR found out the critical time period that may lead to worse prognosis for the time delay of vitrectomy for open globe injury, and thereupon the final time limit of vitrectomy is proposed. These contributions were made by Chinese ophthalmologists. In the past five years, the progress of the eye injury was specially reflected in the breadth of research, which covers optic nerve injury, endophthalmitis etiology, artificial vitreous substitutes, traumatic macular holes, the application of minimally invasive surgery for pediatric eye injuries, etc. Demography-based studies outlined the general condition of eye injuries in China, which has been expected by Chinese researchers for a long time and gives an initial response to foreign peers. What's more significant, they provided convincing data which show that eye injury treatment accounting for one-third of the ophthalmological medical tasks of hospitals at and above county level consumes one-third of ophthalmological medical resources. The two peaks of eye injury, namely children and young adults, are associated with population quality, economy, education and other key fields, which is thought-provoking and assigns more heavy tasks to ophthalmologists.

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