Classification and Regression Tree Analysis for Predicting Visual Outcome after Open-Globe Injuries in Siriraj Hospital

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Objective: *To create a model for predicting visual outcome after open-globe injuries by using data of Siriraj Hospital.*
Material and Method: *Retrospective data of patients presented with open-globe injuries between January 2007 and December 2010 were used to create prognostic model. Seventeen factors at initial presentation were collected and evaluated to develop the model by mean of Classification and Regression Tree analysis (CART). The prognostic tree was validated by using the sample of open-globe patients who presented between January 2011 and July 2011.*
Results: *The information of 231 eyes from 230 patients was analyzed to create a classification tree model. The calculated model composed of the two greatest predictive factors, no light perception (NPL), and presence of relative afferent pupillary defect (RAPD). No patient with NPL at initial examination had vision at the six-month follow-up period. The other patients could be classified and predicted vision by using the presence of RAPD.*
Conclusion: *The classification tree model developed in the present study is easy to calculate and has major significant predictive outcome for the open-globe injured patients.*

Keywords: *Classification and Regression Tree analysis (CART), Open-globe injuries, Open ocular injury, Visual outcome, Ocular trauma*

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Ocular trauma is a common cause of visual loss. An estimated global incidence of eye injuries is 13/100,000 population requiring hospitalization, including 3.5/100,000 population of open-globe injuries, which indicates approximately 203,000 such cases per year[1]. Visual outcome after severe ocular trauma can be profound visual loss, no light perception, evisceration, or enucleation. Having an accurate prognostic model is crucial especially when the choice between various management decisions must be made.

Several studies have reported that the factors significantly predict visual outcome after open globe injuries are initial visual acuity[2-6], presence of a relative afferent papillary defect (RAPD)[3-7], mechanism of injury[3-5,8,9], wound location[3,5,10,11], adnexal trauma[5,7,12], lens damage[3,11], hyphema[13], vitreous hemorrhage[10,14], retinal detachment[4,10,15], intraocular foreign body[6], and endophthalmitis[4].

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In 2008, Schmidt et al[5] described the prognostic model, the classification and regression tree (CART), to predict vision survival after open globe injuries (Fig. 1). They analyzed 214 patients at the Wilmer Ophthalmological Institute and constructed a classification tree using binary recursive partitioning. Factors that have been evaluated include (1) age, (2) gender, (3) initial visual acuity, (4) presence of a RAPD, (5) mechanism of injury, (6) wound location, (7) cause of injury, (8) intraocular foreign body, (9) orbital fracture, (10) lid laceration, (11) hyphema, (12) endophthalmitis, (13) retinal detachment/tear, (14) vitreous hemorrhage, and (15) lens damage. In the classification tree, the presence of a RAPD, poor initial visual acuity, presence of lid laceration, and posterior wound location were the predictive factors of visual loss. The sensitivity to identify correctly a no vision outcome (included no light perception, enucleation, and evisceration outcomes) was 80.4%, and the specificity to identify correctly vision survival was 93.0%.

Compare with data of Thailand, Sunisa Sintuwong et al[6] reported a prospective study to investigate the epidemiology and predictive factors of

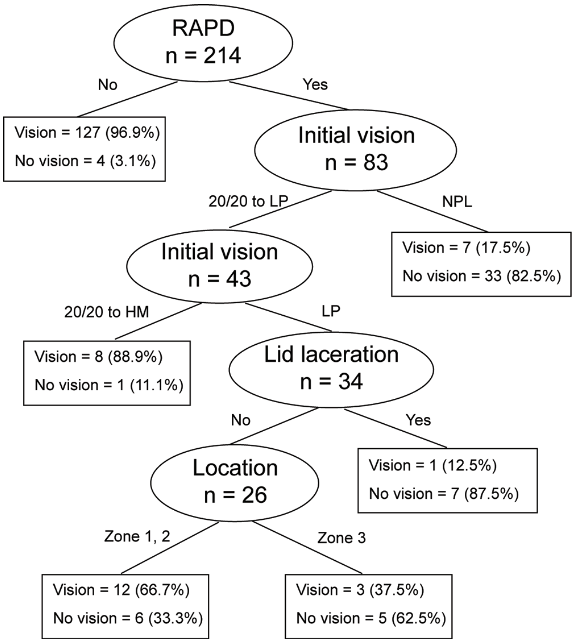

Fig. 1 The original classification and regression tree (CART) model for open globe injuries (G.W. Schmidt's CART).

visual outcome in open globe injuries in Thailand. They analyzed 52 patients who presented between 2009 and 2010. Basic data were obviously different compared with Schmidt et al, such as the presence of a RAPD (15.38% vs. 39.04%), mechanism of injury, laceration (80% vs. 52.11%), intraocular foreign body (36.5% vs. 20.2), and the rate of endophthalmitis (19.3% vs. 0.94%). Therefore, it is questionable if G.W. Schmidt's CART can predict visual outcome precisely for the country of different environment. Our objective is to develop a new CART model using localized area data, and to compare it with the original CART.

Material and Method

Approval was obtained from the Ethics Committee on Human Rights Related to Research Involving Human Subjects of the Faculty of Medicine Siriraj Hospital, Mahidol University to perform the present study. Retrospective data of all patients with open-globe injuries who came to Siriraj Hospital between January 2007 and December 2010 were used to create the prognostic model. Seventeen factors at initial presentation including age, gender, initial visual acuity, presence of a RAPD, mechanism of injury, wound location, wound size, cause of injury, intraocular foreign body, orbital fracture, lid laceration, hyphema, endophthalmitis, retinal detachment/tear, vitreous hemorrhage, lens damage, and time-duration to surgery were collected. Follow-up data, included best-corrected visual acuity of at least six months and complications were recorded. The relationships of vision survival outcome and all factors were assessed using the Chi-square test. The model was developed by mean of Classification and Regression Tree analysis[16-18].

The mechanism of injury was classified as rupture or laceration, according to the Birmingham Eye Trauma Terminology (BETT) system[19]. Wound location was defined using the Ocular Trauma Classification Group. Zone I injuries were confined to the cornea, zone II injuries involved the anterior 5 mm of the sclera, and zone III injuries involved full-thickness scleral defects more posterior than 5 mm from the limbus. No vision at follow-up period was defined as no light perception or evisceration/ enucleation.

Univariate Chi-square analysis was used to determine which factors were related to visual outcome. Classification and Regression Tree Analysis was used to construct the tree model.

The prognostic tree was validated by using the sample of open-globe patients presented between January 2011 and July 2011.

Results

In the four-year study period, 236 patients (237eyes) presented with open-globe injury to Siriraj Hospital. Six patients who could not be assessed for actual initial visual acuity were excluded.

There were 86.6% (200/231) males and 13.4% (31/231) females. The age of the patients ranged from 3 to 83 years, with a mean of 35 years. The majority of the injuries were caused by accidents (206/231, 89.2%) and assault (25/231, 10.8%). Half of open-globe injuries (118/231, 51%) occurred at workplace. Of the 231 open globes, 190 (82.3%) globes were lacerated and 41 (17.7%) globes were ruptured. Most patients (132/231, 42.9%) had zone I injuries, 27.3% (63/231) had zone II injuries, and 15.9% (36/231) had zone III injuries. The presenting visual acuity was 20/40 or better in 10.8% (25/231) of patients, 20/200-20/50 (43/231) in 18.6% of patients, Count finger - 19/200 in 21.6% (50/231) of patients, light perception (LP) or hand motion (HM) in 37.7% (87/231) of patients, and NPL in 11.3% (26/231) of patients. An RAPD was present in 23.4% (54/231) of patients, and 17.3% (40/231) of patients had lid lacerations. Twenty-one (9.1%) patients developed endophthalmitis and had variable visual outcome. All patients had at least six months follow-up. The final visual acuity was 20/40 or better in 34.6% (80/231) of patients, 20/200-20/50 in 28.6% (66/231) of patients, Count finger-19/200 in 7.4% (17/231) of patients, LP or HM in 10.8% (25/231) of patients, and NPL in 12.6% (29/231) of patients, and the enucleation rate was 6% (14/231).

For visual survival outcome, univariate analysis showed that initial visual acuity ($p<0.001$), the presence of RAPD ($p<0.001$), mechanism of injury ($p<0.001$), wound location ($p<0.001$), wound size ($p<0.001$), cause of injury ($p = 0.002$), orbital fracture ($p<0.001$), lid laceration ($p<0.001$), presence of gross hyphema ($p<0.001$), retinal detachment/tear ($p<0.001$), vitreous hemorrhage ($p<0.001$), and lens damage ($p<0.003$) were the significant predictive factors (Table 1).

The calculated model by mean of Classification and Regression Tree Analysis (CART) showed that there were two greatest predictive factors, no light perception (NPL) and presence of relative afferent pupillary defect (RAPD). No patient with NPL at initial examination had vision at six months follow-up period. The other patients could be classified and predicted vision by using the presence of RAPD. Half of the patients who presented with initial visual acuity better than NPL and presence of RAPD finally had no vision, especially in case with zone III injury (Fig. 2). The sensitivity of the tree to identify correctly a no vision outcome was 74.4%, and the specificity to identify correctly vision survival was 97.3%. Accuracy was 93.1% (Table 2).The original CART (G.W. Schmidt's CART) had sensitivity, specificity, and accuracy at 74.4% (32/43), 96.3% (181/188), 92.2% (213/231), respectively (Table 2).

The information of patient presented between January 2011 and July 2011 were used to validate the prognostic tree. The new tree (Siriraj's CART) had sensitivity 88.9% (8/9), specificity 93.8% (30/32) and accuracy 92.7% (38/41) (Table 3). The original tree (G.W. Schmidt's CART) had sensitivity 77.8% (7/9), specificity 90.6% (29/32), and accuracy 87.8% (36/41) (Table 3).

Discussion

There were many different patient's factors in the present study as compared to Schmidt's study[5] such as less numbers of cases presenting with initial visual acuity of NPL (11.2% vs. 18.6%), presence of RAPD (22% vs. 39%), rupture mechanism (17.7% vs. 47.8%), presence of orbital fracture (4.8% vs. 14.9%), much more presence of intraocular foreign body (32% vs. 17%), and a higher endophthalmitis rate (9.52% vs. 0.93%). Half of the patients had accidental injuries at work place, most cases with intraocular foreign body. This study compare with a prospective study from Thailand, Sunisa et al[6], which had the same proportion of laceration mechanism, presence of intraocular foreign body, wound size, but had more patients with initial visual acuity of NPL (11.2% vs. 5.7%), presence of RAPD (22% vs. 15.4%), and less endophthalmitis (9.52% vs. 19.3%).

Univariate analysis showed the same factors associated with no vision as Schmidt's study. An initial visual acuity of NPL was associated with very poor visual outcome ($p<0.001$). All of 26 patients presenting with an initial visual acuity of NPL had no vision, and 10 patients (38%) underwent enucleation. The original CART study, Schmidt et al found that 85% (33/39) of patients presenting with an initial visual acuity of NPL underwent no vision. C Yu Wai Man et al[20] described in their study of 100 patients with open-globe injuries that an initial visual acuity of NPL was associated with only 1.3% (1/100) of the vision survival group.

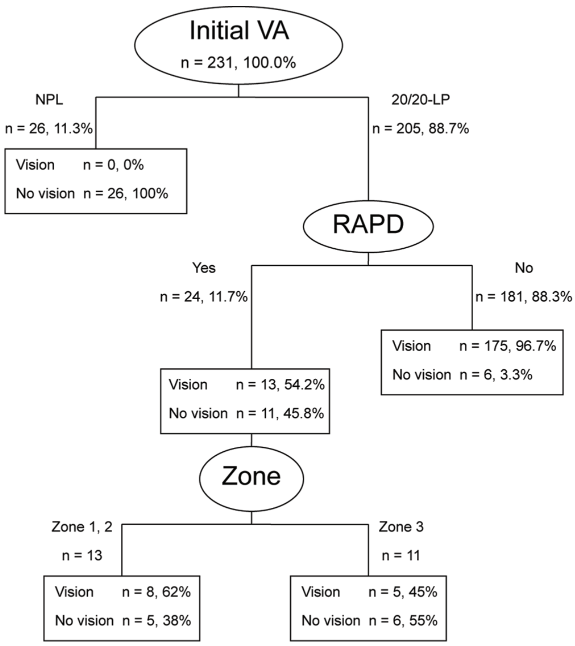

Fig. 2 The classification and regression tree (CART) model for open globe injuries created by using data of Siriraj Hospital (Siriraj's CART).

Table 1. Correlation between patient characteristics and final visual outcome

	Vision (n = 188)	No vision (n = 43)	Odds ratio (95% CI)	*p*-value#
Age (years)				0.454
2-9	11 (5.9%)	1 (2.3%)	1.0	
10-29	73 (38.8%)	17 (39.5%)	2.6 (0.3, 21.2)	
30-49	66 (35.1%)	14 (32.6%)	2.3 (0.3, 19.6)	
50-69	29 (15.4%)	6 (14.0%)	2.3 (0.2, 21.1)	
70+	9 (4.8%)	5 (11.6%)	6.1 (0.6, 62.2)	
Sex				0.109
Male	166 (88.3%)	34 (79.1%)	1.0	
Female	22 (11.7%)	9 (20.9%)	2.0 (0.8, 4.7)	
Initial VA			N/A	<0.001*
NPL	-	26 (60.5%)		
LP	34 (18.1%)	12 (27.9%)		
HM	37 (19.7%)	4 (9.3%)		
CF-19/200	49 (26.0%)	1 (2.3%)		
20/200-20/50	43 (22.9%)	-		
>20/40	25 (13.3%)	-		
RAPD				<0.001*
No	171 (91.0%)	6 (14.0%)	1.0	
Yes	13 (6.9%)	36 (83.7%)	78.9 (28.1, 221.5)	
No data	4 (2.1%)	1 (2.3%)		
Mechanism				<0.001*
Laceration	165 (87.8%)	25 (58.1%)	1.0	
Rupture	23 (12.2%)	18 (41.9%)	5.2 (2.4, 10.9)	
Wound location				<0.001*
Zone I	120 (63.8%)	12 (27.9%)	1.0	
Zone II	56 (29.8%)	7 (16.3%)	1.2 (0.5, 3.3)	
Zone III	12 (6.4%)	24 (55.8%)	20.0 (8.0, 49.8)	
Wound size (mm)				<0.001*
<10	163 (86.7%)	12 (27.9%)	1.0	
≥10	25 (13.3%)	31 (72.1%)	16.8 (7.7, 37.0)	
Cause of injury				0.002*
Accidental	174 (92.6%)	32 (74.4%)	1.0	
Assault	14 (7.4%)	11 (25.6%)	4.3 (1.8, 10.2)	
Intraocular foreign body				0.293
No	129 (68.6%)	16 (37.2%)	1.0	
Yes	57 (30.3%)	11 (25.6%)	1.6 (0.7, 3.6)	
No data	2 (1.1%)	16 (37.2%)		
Orbital fracture				<0.001*
No	187 (99.5%)	33 (76.7%)	1.0	
Yes	1 (0.5%)	10 (23.3%)	56.7 (7.0, 457.5)	
Lid laceration				<0.001*
No	169 (89.9%)	22 (51.2%)	1.0	
Yes	19 (10.1%)	21 (48.8%)	8.5 (3.9, 18.2)	
Hyphema				<0.001*
No	130 (69.1%)	11 (25.6%)	1.0	
Yes	58 (30.9%)	32 (74.4%)	6.5 (3.1, 13.8)	
Endophthalmitis				0.260
No	172 (91.5%)	37 (86.0%)	1.0	
Yes	16 (8.5%)	6 (14.0%)	1.7 (0.6, 4.7)	

VA = visual acuity; NPL = no light perception; LP = light perception; HM = hand motion; CF = counting finger; RAPD = relative afferent pupillary defect

Chi-square test

* Statistical significance

Table 1. (cont.)

	Vision (n = 188)	No vision (n = 43)	Odds ratio (95% CI)	*p*-value#
Retinal detachment/tear				<0.001*
No	126 (67.0%)	3 (7.0%)	1.0	
Yes	58 (30.9%)	22 (51.2%)	15.9 (4.6, 55.4)	
No data	4 (2.1%)	18 (41.8%)		
Vitreous hemorrhage				<0.001*
No	111 (59.1%)	6 (14.0%)	1.0	
Yes	70 (37.2%)	23 (53.5%)	6.1 (2.4, 15.7)	
No data	7 (3.7%)	14 (32.5%)		
Lens damage				0.003*
No	103 (54.8%)	21 (48.8%)	1.0	
Yes	80 (42.5%)	3 (7.0%)	0.2 (0.1, 0.6)	
No data	5 (2.7%)	19 (44.2%)		
Time (hours)				0.120
≤24	134 (71.3%)	35 (81.4%)	1.0	
>24	53 (28.2%)	7 (16.3%)	0.5 (0.2, 1.2)	
No data	1 (0.5%)	1 (2.3%)		

VA = visual acuity; NPL = no light perception; LP = light perception; HM = hand motion; CF = counting finger; RAPD = relative afferent pupillary defect

Chi-square test

* Statistical significance

Table 2. The accuracy of the tree in predicting visual outcome (n = 231)

CART	Follow-up visual outcome		Total	Sensitivity	Specificity	Accuracy
	Vision (n = 188)	No vision (n = 43)				
Siriraj's						
Vision	183	11	194	74.4% (32/43)	97.3% (183/188)	93.1% (215/231)
No vision	5	32	37			
Schmidt's						
Vision	181	11	192	74.4% (32/43)	96.3% (181/188)	92.2% (213/231)
No vision	7	32	39			

CART = classification and regression tree

Table 3. CART validation (n = 41)

CART	Follow-up visual outcome		Total	Sensitivity	Specificity	Accuracy
	Vision (n = 32)	No vision (n = 9)				
Siriraj's						
Vision	30	1	31	88.9% (8/9)	93.8% (30/32)	92.7% (38/41)
No vision	2	8	10			
Schmidt's						
Vision	29	2	31	77.8% (7/9)	90.6% (29/32)	87.8% (36/41)
No vision	3	7	10			

In the present series, all patients presenting with an initial visual acuity better than 20/200 had vision survival outcome. Only one of 50 patients presenting with an initial visual acuity CF-19/200 who associated with endophthalmitis and recurrent retinal detachment resulted in no vision. In concurrence with the Schmidt et al study, all patient with initial visual acuity better than 20/400 had vision survival outcome.

Presence of an RAPD was also a strong predictor of visual outcome in our study ($p<0.001$). The absence of an RAPD led to 96.6% (171/177) chance of visual survival and 3.4% (6/177) of no vision. Among of the initial absence of RAPD patients who became no vision, three of six patients had endophthalmitis. Schmidt et al and C Yu Wai Man et al reported that about 97% of patients presented with absence of RAPD had vision survival. In the present study, 73.5% (36/49) of patients presenting with presence of RAPD had no vision.

Posterior wound location was associated with visual loss in the present study (p<0.001). Zone III injuries (involved full-thickness scleral defects more posterior than 5mm from the limbus) had potential to damage the retina and optic nerve and thus carried poor visual prognosis. We found that one-third (12/36) of patients who had zone III injuries had no vision.

About one-half (21/40) of open-globe injured patients who associated with lid lacerations preceded to eventual no vision outcome in the present study. Support for this result, Schmidt et al reported the same outcome proportion and concluded that lid laceration was a significant predictive factor. Additionally, Rahman et al[7] described in their study of 107 patients with open-globe injuries that the presence of lid laceration was associated with eventual enucleation.

The data of the present study from January 2007 to July 2011, there were 51 patients with no vision outcome, and the rate of secondary enucleation or evisceration was 33.3% (17/51). This rate was higher than many previous reports such as Rofail et al[21] (15%), Rahman et al[7] (12%), and Dunn et al[8] (11%), Pieramici et al[3] (24%), Casson et al[22] (20%) and Schmidt et al[5] (26%). No one in this series was treated with primary enucleation. After primary repair, some cases were considered for early enucleation to reduce the risks of sympathetic ophthalmia. High enucleation or evisceration rate in the present study was obviously related with presence of facial bone fracture more than 50% (8/15) of the fracture cases.

CART model developed in the present study confirmed that the two greatest predictive factors are initial visual acuity of no light perception (NPL) and presence of relative afferent pupillary defect (RAPD). No patient with NPL at initial examination had vision at six months follow-up period. Half of the patients presented with initial visual acuity better than NPL and presence of RAPD finally had no vision, especially in case with zone III injury. This model had slightly higher prognostic accuracy than the original CART when use this model with patients in area environment and population base similar to central Thailand.

Conclusion

The classification tree model developed in the present study is easy to calculate and has major significant predictive outcome for the open-globe injured patients.

What is already known on this topic?

Several previous studies have reported that the factors that significantly predict visual outcome after open globe injuries are initial visual acuity, presence of a relative afferent papillary defect (RAPD), mechanism of injury, wound location, adnexal trauma, lens damage, hyphema, vitreous hemorrhage, and retinal detachment, intraocular foreign body, endophthalmitis.

In 2008, Schmidt et al described the prognostic model, the Classification and Regression Tree (CART), to predict vision survival after open globe injuries. The sensitivity to identify correctly a no vision outcome (included no light perception, enucleation, and evisceration outcomes) was 80.4%, and the specificity to identify correctly vision survival was 93.0%

Compare with data of Thailand, basic data were different from Schmidt's report. Therefore, it is questionable if G.W. Schmidt's CART can predict visual outcome precisely for the country of different environment. Our objective was to develop a new CART model, using localized area data, and to compare it with the original CART.

What this study adds?

The present study included 271 open globe injured patients, which is more than any previous study in Thailand, and more than Schmidt's study. The results confirmed the difference of many patient's basic factors compared to the Schmidt's study.

The CART model developed in this study is easy to calculate and has slightly higher prognostic accuracy than the original CART when it is used with patients in area environment and population base similar to central Thailand.

Potential conflicts of interest

None.

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แผนภูมิทำนายการมองเห็นของผู้ป่วยหลังได้รับบาดเจ็บทางตาที่มีบาดแผลทะลุในโรงพยาบาลศิริราช

ณัฐพงศ์ เมฆาสิงหรักษ์, จักรพงศ์ นะมาตร์

วัตถุประสงค์: *เพื่อสร้างแผนภูมิทำนายการมองเห็นของผู้ป่วยหลังได้รับบาดเจ็บทางตาที่มีบาดแผลทะลุโดยใช้ข้อมูลของโรงพยาบาลศิริราช*

วัสดุและวิธีการ: *ข้อมูลของผู้ป่วยที่ได้รับบาดเจ็บทางตาที่มีบาดแผลทะลุและมารับการรักษาในโรงพยาบาลศิริราชระหว่างเดือนมกราคม พ.ศ. 2550 ถึง เดือนธันวาคม พ.ศ. 2553 ถูกนำมาใช้ในการสร้างแผนภูมิเพื่อทำนายการมองเห็น โดยตัวแปรที่เป็นลักษณะที่ตรวจพบขณะผู้ป่วยมาโรงพยาบาลทั้งหมด 17 ตัวแปร ได้รับการวิเคราะห์โดยวิธี Classification and Regression Tree แผนภูมิที่สร้างขึ้นถูกนำมาประเมินการใช้งานจริงอีกครั้งโดยใช้ข้อมูลจากผู้ป่วยที่ได้รับบาดเจ็บทางตาที่มีบาดแผลทะลุและมารับการรักษาระหว่างเดือนมกราคม พ.ศ. 2554 ถึง เดือนกรกฎาคม พ.ศ. 2554*

ผลการศึกษา: *ข้อมูลของผู้ป่วยทั้งหมด 230 ราย ถูกนำมาวิเคราะห์และใช้สร้างแผนภูมิทำนายการมองเห็น พบว่าการมองไม่เห็นแสง (no light perception) และการมีภาวะ RAPD ตั้งแต่มาโรงพยาบาลเป็น 2 ตัวแปรที่สำคัญที่สุดในการทำนายการมองเห็นของผู้ป่วย ไม่มีผู้ป่วยรายใดที่มองไม่เห็นแสงตั้งแต่มาที่โรงพยาบาลกลับมามองเห็นได้เลยหลังจากติดตามไปเป็นระยะเวลา 6 เดือน ผู้ป่วยในกลุ่มที่ยังมีการมองเห็นอยู่จะถูกแบ่งกลุ่มโดยการมีภาวะ RAPD*

สรุป: *แผนภูมิทำนายการมองเห็นที่สร้างขึ้นจากการศึกษานี้สามารถนำไปประยุกต์ใช้ได้ง่ายและทำนายการมองเห็นของผู้ป่วยหลังได้รับบาดเจ็บทางตาที่มีบาดแผลทะลุได้อย่างน่าเชื่อถือ*