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Factors associated with seizure-related motor vehicle accidents among patients with epilepsy in West China

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ABSTRACT

Purpose: This study was conducted to investigate the relevant demographics and clinical factors contributing to seizure-related motor vehicle accidents in west China.

Methods: All driving patients who visited our epilepsy clinic in the West China Hospital, between October 2012 and October 2016, were invited to participate. Data on social demographics, clinical features, and motor vehicle accidents were collected during structured interviews. Binary logistic regression was used to identify factors associated with seizure-related motor vehicle accidents.

Results: In total, 519 patients reported driving after being diagnosed with epilepsy. Among them, thirty-nine (7.5%) patients experienced at least one seizure-related motor vehicle accidents. Patients who had seizure-free intervals ≥2 years had a 89% reduced chance of crashing compared to patients with shorter intervals. Logistic regression revealed that the interval of seizure freedom (B = -0.384, P = 0.007), number of antiepileptic drugs (AEDs) taken (B = 0.400, P = 0.041), and type of motor vehicle (B = 0.798, P = 0.021) were independently associated with seizure-related motor vehicle accidents.

Conclusion: The interval of seizure freedom, number of AEDs taken, and type of motor vehicle should be considered when counseling patients with epilepsy on driving. A longer seizure-free interval suggested a compromised risk of seizure-related motor vehicle accidents.

1. Introduction

Epilepsy is characterized by unpredictable seizures [1]. Loss of consciousness during seizures may influence the driving ability of patients with epilepsy (PWE) and result in motor vehicle accidents (MVA) [2]. In China, PWE have been forbidden from driving motor vehicles since 1988, according to the Regulations of the People's Republic of China on Road Traffic [3]. Provisions on the Application for and Use of Driving Licenses, which took effect in 2004, ban all PWE from obtaining a driver's license [4]. In modern society, driving is an indispensable part of life from both an economic and social perspective [5]. The number of cars is growing rapidly in China; in 2017, China had 385 million motor vehicle drivers with an annual increase of over 30 million [6]. In 2014, a man with epilepsy in Yichang city, China, experienced an epileptic seizure while driving, resulting in four deaths and eight injuries. He was sentenced to life imprisonment for "dangerous methods of endangering public safety." [7] As driving is increasingly important for independent living, social activities, and career opportunities, 19.5% of PWE still drive illegally in China [8,9]. To strike a balance between patients' quality of life and the safety of the public, and to provide information to Chinese doctors and legislatures, factors contributing to seizure-related MVA must be clarified. We therefore conducted this study to investigate the relevant demographic and clinical factors contributing to seizure-related MVA in West China.

2. Materials and methods

2.1. Study setting and procedures

Between October 2012 and October 2016, all adult patients who came to our epilepsy out clinic in the West China Hospital, a tertiary referral center in Chengdu city (population more than 14 million), were

Abbreviations: AEDs, antiepileptic drugs; MVA, motor vehicle accidents; PWE, patients with epilepsy

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Table 1
Demographic features of PWE who experienced seizure-related motor vehicle accidents and those who did not while driving.

Variable	All (n = 519)	Seizure-related MVA (n = 39)	No seizure-related MVA (n = 480)	X^2/t	p-Value
Male	390 (75.1)	31 (79.5)	359 (74.8)	0.426	0.514
Age (years)(N,%)				6.864	0.231
18–20	59 (11.4)	8 (13.6)	51 (86.4)		
21–30	243 (46.8)	15 (6.2)	228 (93.8)		
31–40	110 (21.2)	6 (5.5)	104 (94.5)		
41–50	72 (13.9)	7 (9.7)	65 (90.3)		
51–60	24 (4.6)	3 (12.5)	21 (87.5)		
> 60	11 (2.1)	0 (0.0)	11 (100.0)		
Married	380 (73.2)	32 (82.1)	348 (72.5)	1.678	0.195
Location (N,%)				4.502	**0.034***
Rural	138 (26.6)	16 (11.6)	122 (88.4)		
Urban or suburban	381 (73.4)	23 (6.0)	358 (94.0)		
Education status (N,%)				8.849	0.115
Illiterate	5 (1.0)	1 (20.0)	4 (80.0)		
Primary school	22 (4.2)	4 (18.2)	18 (81.8)		
Middle school	123 (23.7)	14 (11.4)	109 (88.6)		
High school	139 (26.8)	9 (6.5)	130 (93.5)		
College/Bachelor	213 (41.0)	10 (4.7)	203 (95.3)		
Graduate	17 (3.3)	1 (5.9)	16 (94.1)		
Occupational status (N,%)	309(59.5)	21(53.8)	288(60.0)	0.567	0.451
Personal monthly income (N,%)				3.684	0.055
≤2000 yuan	256(49.3)	25(9.8)	231(90.2)		
> 2000 yuan	263(50.7)	14(5.3)	249(94.7)		
Household monthly income (yuan, mean ± SD)	7970.65 ± 10,056.39	5463.33 ± 5158.75	8172.85 ± 10,328.56	1.421	0.156

p value for factors statistically significantly associated with seizure-related MVA appear in bold.
Abbreviation: MVA, motor vehicle accidents; PWE, patients with epilepsy.
* $p < 0.05$.

invited to participate in this study. Eligible patients were brought to a quiet room for a semi-structured face to face interview in the out clinic. The inclusion criteria were as follows: (1) validated diagnosis of epilepsy by two neurologists, differences in opinion were resolved by consensus, (2) over 18-year old (the legal age for driving in China), (3) history of driving after being diagnosed with epilepsy, and (4) at least 1-year diagnosis of epilepsy. Patients were excluded if they met any of the following criteria: known condition other than epilepsy that forbade them from driving a motor vehicle according to the Provisions on the Application for and Use of Driving Licenses, such as heart disease, Meniere's disease, conversion disorder, paralysis agitans, psychosis, dementia, drug abuse, and other diseases that may affect physical activity [4].

The study was approved by the Ethics Committee of West China Hospital, Sichuan University. We informed all participants about the purpose of this study and obtained their written informed consent. The participants' anonymity was guaranteed.

2.2. Data collection

Information gathered during the structured interview: (1) sociodemographic status: gender, age, marriage, location (urban or suburban/rural), educational and occupational status, as well as personal and household monthly income; (2) clinical information: age at seizure onset, aura (no aura, aura < 1 min, or aura ≥1 min), interval of seizure freedom (for patients with MVA, the seizure-free interval is the time from the last seizure to the accident), seizure types, the number of antiepileptic drugs (AEDs), EEG results, the time period of controlled seizure, and whether the applicants experienced seizures only nocturnally; and (3) driving and accident information: the type of motor vehicle, severity of vehicle accident, whether patients obtained a driver's license, whether patients knew of driving restrictions, whether patients reported their condition to the department of driving management, and whether patients consulted their doctor or their driving school. Severe injuries are defined as requiring hospitalization, and mild or moderate injuries are defined as requiring only outpatient treatment [32].

2.3. Data analysis

Descriptive statistics of the patients were conducted. Quantitative data were expressed as the mean ± SD or summarized as proportions. Then, the sample was divided into two groups that patients had seizure-induced MVA (patients who experienced MVA at their first seizure attack were not included) and patients who do not. Univariate binary logistic regression was performed to detect the possible association between clinical and social demographic variables and seizure-related MVA. Variables that yielded $P < 0.1$ in the univariate binary logistic regression and clinical factors that were associated with seizure-related MVA in previous studies [2,11,13–18] were entered into a model of multiple logistic regression. The multicollinear test was performed before these variables were entered into the regression model. To further explore the potential factors related to seizure-induced MVA, we compared clinical features between patients who were involved in seizure-related MVA and who were only involved in seizures without MVA [8].

SPSS 22.0 (SPSS Inc Chicago, Illinois) was used to perform all analyses. All P-values were two-sided, with $P < .05$ considered statistically significant.

3. Results

3.1. Demographic, clinical, and driving characteristics

Between October 2012 and October 2016, a total of 3228 patients came to our epilepsy clinic, among them only 536 patients who had a history of driving after being diagnosed with epilepsy were invited to participate in this study. Out of the 536 driving patients, 13 patients failed to complete the survey or declined to participate, and four patients had intellectual disability; thus they were excluded. In total, only 519 patients had completed the survey and were eligible for this study. Demographics and clinical characteristics for the 519 driving patients are summarized in Tables 1 and 2.

Out of the 519 driving patients, 410 (79.0%) patients possessed a driver's license, while 109 (21.0%) patients were driving without a license, and only 163 (31.4%) patients were aware of the driving

Table 2
Clinical features and driving information of PWE who experienced seizure-related motor vehicle accidents and those who did not while driving.

Variable	All(n = 519)	Seizure-related MVA (n = 39)	No seizure-related MVA (n = 480)	X^2/t	p-Value
Age at seizure onset, mean (years, mean ± SD)	25.02 ± 12.83	22.87 ± 11.91	25.19 ± 12.9	1.088	0.277
Has seizure only nocturnally (N,%)	119 (22.9)	4 (10.3)	115 (24.0)	3.832	0.050
Aura (N,%)				4.353	0.113
No aura	346 (66.7)	26 (7.5)	320 (92.5)		
< 1min	120 (23.1)	12 (10.0)	108 (90.0)		
≥ 1min	53 (10.2)	1 (1.9)	52 (98.1)		
Interval of seizure freedom (N,%)				14.455	**0.006***
0-3month	223 (43.0)	26 (66.7)	197 (41.0)		
3-6month	71 (13.7)	4 (10.3)	67 (14.0)		
6-12month	69 (13.3)	5 (12.8)	64 (13.3)		
1-2year	63 (12.1)	3 (7.7)	60 (12.5)		
≥ 2year	93 (17.9)	1 (2.6)	92 (19.2)		
Seizure type (N,%)				8.491	**0.014***
Simple partial	30 (5.8)	1(3.3)	29 (96.7)		
Complex partial	138 (26.6)	18 (13.0)	120 (87.0)		
GTCS + secondary GTCS	351 (67.6)	20 (5.7)	331 (94.3)		
The number of AEDs (N,%)				12.919	**0.012***
0	30 (5.8)	2 (6.7)	28 (93.3)		
1	275 (53.0)	11 (4.0)	264 (96.0)		
2	164 (31.6)	18 (11.0)	146 (89.0)		
3	39 (7.5)	7 (17.9)	32 (82.1)		
≥ 4	11 (2.1)	1 (9.1)	10 (90.9)		
EEG (N,%)				3.402	0.182
Non-specific abnormality	278 (53.6)	16 (5.8)	262 (94.2)		
Epileptiform EEG	182 (35.1)	19 (10.4)	163 (89.6)		
Unknown	59 (11.4)	4 (6.8)	55 (93.2)		
The time period of controlled seizure (N,%)				9.483	**0.024***
Active	282 (54.3)	29 (10.3)	253 (89.7)		
Sustainable	139 (26.8)	8 (5.8)	131 (94.2)		
Reduction	63 (12.1)	1 (1.6)	62 (98.4)		
Drugs attenuating	35 (6.7)	1 (2.9)	34 (97.1)		
Obtaining a License (N,%)					
Yes	410 (79.0)	26 (66.7)	384 (80.0)	3.865	**0.049***
No	109(21.0)	13(33.3)	96(20.0)		
Awareness of law (N,%)	163 (31.4)	14 (35.9)	149 (31.0)	0.385	0.530
The type of motor vehicle				9.252	**0.002***
Cars	375 (72.3)	20 (5.3)	355 (94.7)		
Motorcycle/Tricycle	144 (27.6)	19 (13.2)	125 (86.8)		

p value for factors statistically significantly associated with seizure-related MVA appear in bold.
Abbreviation: Abbreviation: AEDs, antiepileptic drugs; MVA, motor vehicle accidents; PWE, patients with epilepsy; GTCS, generalized tonic-clonic seizure.
* $p < 0.05$.

Table 3
Multiple logistic regression of variables associated with seizure-related motor vehicle accidents in patients with epilepsy.

Variable[a]	*B*	*S.E.*	*Sig.*	*Exp(B)*	*95%C.I for EXP(B)*	
					Lower	Upper
Interval of seizure freedom	−0.384	0.142	0.007	0.681	0.515	0.900
The number of AEDs	0.400	0.195	0.041	1.491	1.017	2.187
The type of accidents	0.798	0.346	0.021	2.221	1.127	4.377
Constant	−2.661	0.496	0.000	0.070		

Abbreviation: AEDs, antiepileptic drugs.
[a] location, interval of seizure freedom, seizure types, the number of AEDs, the time period of controlled seizure, type of motor vehicle, obtaining a license were entered into the model. Only significantly associated factors were listed in this table.

restrictions. Among the 39 patients with seizure-related MVA, only nine (23.1%) patients consulted their doctor, but none of them consulted their driving school or reported their disease to the police or to the department of transportation. Regarding the degree of injury, the majority (82.0%) of patients reported mild or moderate injury, and only two (5.1%) patients experienced severe physical injury.

3.2. Risk factors associated with seizure-related MVA

Univariate binary regression (Tables 1 and 2) showed that location (P = 0.034), interval of seizure freedom (P = 0.006), seizure types (P = 0.014), the number of AEDs (P = 0.012), the time period of controlled seizure (P = 0.024), type of motor vehicle (P = 0.002), and obtaining of a license (P = 0.049) were associated with seizure-related MVA.

As to seizure-free interval, patients with a seizure-free interval > or = 2 years had a reduced chance of 89% for seizure-related MVA compared to patients with shorter intervals (OR: 0.111, 95% CI: 0.015–0.819). The odds of seizure-related MVA was reduced by 75% (OR: 0.247, 95% CI: 0.086–0.706) for patients with 1-year or longer seizure-free interval, 63% (OR: 0.367, 95% CI: 0.170–0.789) for patients more than 6 months, 65% (OR: 0.348, 95% CI: 0.175–0.694) for patients more than 3 months, respectively.

Multiple logistic regression revealed that interval of seizure freedom (P = 0.007), the number of AEDs (P = 0.041), and the type of motor vehicle (P = 0.021) were independently and simultaneously associated with seizure-related MVA (Table 3).

3.3. Seizures and seizure-related MVA while driving

A total of 78 PWE experienced seizure while driving, among which 39 PWE experienced seizure-related MVA. A comparison of characteristics between driving patients who had seizure-related MVA and those

Table 4
Comparison of characteristics between driving patients who had seizure-related MVA and those who only experienced seizures while driving.

Variable	Seizure-related MVA (N = 39)%	Only Seizures (N = 39)%	P-value
Aura (N,%)			**0.016***
No	26 (66.7)	17 (43.6)	
< 1min	12 (30.8)	14 (35.9)	
≥1min	1 (2.6)	8 (20.5)	
Seizure type (N,%)			0.096
Simple partial seizure	1 (2.6)	6 (15.4)	
Complex partial seizure	18 (46.2)	18 (46.2)	
GTCS + secondary GTCS	20 (51.3)	15 (38.5)	
Numbers of AEDs (N,%)			0.167
Mono-therapy	13 (33.3)	19 (48.7)	
Poly-therapy	26 (66.7)	20 (51.3)	
The interval of seizure free (N, %)			0.793
0-3month	26 (66.7)	29 (74.4)	
3-6month	4 (10.3)	2 (5.1)	
6-12month	5 (12.8)	3 (7.7)	
1-2 year	3 (7.7)	3 (7.7)	
≥2 years	1 (2.6)	2 (5.1)	
The type of accidents (N,%)			0.495
Cars	20 (51.3)	23 (59.0)	
Motorcycle/Tricycle	19 (48.7)	16 (41.0)	

p value for factors statistically significantly associated with seizure-related MVA appear in bold.
Abbreviation: AEDs, antiepileptic drugs; MVA, motor vehicle accidents; GTCS, generalized tonic-clonic seizure.
* $P < 0.05$.

who only experienced seizures while driving was summarized in Table 4. A significant difference was observed in aura ($P = 0.016$) between them.

4. Discussion

4.1. Summary of the study results

Although it is banned in China, this study has found that a portion of PWE still drive illegally. Among this group, 39 (7.5%) PWE experienced seizure-related MVA at least once, which is similar to a recent report of 8.7% in Maryland [30]. In this sample, we analyzed motor vehicle accidents induced by seizure in patients with epilepsy and concluded the characteristics of seizure-related MVA. These findings revealed that the interval of seizure freedom, the number of AEDs, and the type of motor vehicle were independently associated with seizure-related MVA. In addition, a longer seizure-free interval suggested a compromised risk of seizure-related MVA.

4.2. Risk factors associated with seizure-related MVA

The interval of seizure freedom was associated with seizure-related MVA, which is consistent with several previous studies [22,23]. The rates of seizure-related MVA were reduced significantly by 3- and 6-month seizure-free intervals [15,30,33]. In this sample, we described the odds for motor vehicle accidents during seizure was reduced by 75% at 1-year seizure-free interval, which is lower than a study described a reduction up to 93% [26]; and patients with a 2-year seizure-free interval still had a subtle risk of seizure-related MVA; different driving restrictions, road conditions, type of vehicle, small sample sizes, and other factors between nations may contribute to this difference.

This study observed that the number of AEDs was associated with seizure-related MVA, which consistent with previous studies in other nations [14,21]. In this sample, 66.7% patients who had experienced seizure-related MVA were on poly-therapy, which indicated that AEDs poly-therapy could be a marker of disease severity and its side effects may compromise driving ability [20,27,31].

The type of motor vehicle was also a factor associated with seizure-related MVA. A study in Thailand demonstrated a similar result that motorcycle accidents caused the majority of traffic injuries [13]. Motorcycle accidents were almost 12 times more likely than other MVA [19]. Thus, we suggest that patients should be warned that driving motorcycle may associate with an increased risk of seizure-related MVA.

The presence of reliable aura was once considered protective against MVA [16,26]. In this sample, aura was not significantly associated with seizure-related MVA in regression models. However, when we compared driving patients who experienced seizure-induced MVA and those who experienced only seizures without MVA, we found that patients with aura ≥ 1 min rarely experienced seizure-induced MVA. This may indicated that the length of aura is related to seizure-related MVA, but aura does not completely protect against seizure-related MVA [11,32].

4.3. Patients education and legal issues

21.0% patients were driving without license, and only 35.9% acknowledged that they knew the details of the driving restriction, which is consistent with our previous study [8]. Driving ban is not widely known among patients with epilepsy. Moreover, patients may not voluntarily report their driving condition to doctors [28,33]. Hence, doctors should take initiative to ask patients about their driving conditions, inform them of the driving restriction for PWE, and provide professional advice.

Driving restriction for PWE varys from country to country. In some countries, patients can drive again if no seizures relapse during the restriction period (usually 3 to 24 months) [20,28,29,34]. However, driving restriction is strictly and completely banned for all PWE in China, which has not changed since 1988 [3]. In this sample, the majority of patients who experienced seizure-related MVA had mild or moderate injuries; these injuries are often less severe and less lethal compared with other causes of MVA [9,12], particularly compared with alcohol [10]. In addition, driving is of such great importance that the imposed restrictions also may unduly harm the welfare of these individuals [18]. Thus, more detailed and operational driving restrictions are required in China. In 2011, one study in China collected opinion of fifty epilepsy experts in tertiary hospitals suggested that individuals with IGE (idiopathic generalized epilepsy) should refrain from driving for an average of 16.59 ± 12.26 months [18]. The present study has provided more evidence regarding this issue in China, showed that a longer seizure-free interval reduced the risk of seizure-related MVA; patients with a seizure-free interval ≥2 years had a 89% reduced chance of crashing. More research is still needed in order to provide reliable and detailed information for Chinese doctors, legislators, and authorities.

4.4. Limitations

This study has several limitations. PWE were recruited from a tertiary hospital, therefore the results from West China may not be generalizable to other regions due to the possibility of different inter-regional circumstances; however, these findings on the factors likely to influence PWE driving issue (the main focus of this study), could generally be applicable to all PWE. Data on driving and clinical information in this sample was based on self-report and prone to responder bias; although this study was large, we acknowledge that the sample sizes used in the models were still too small to provide precise estimates. Previous study found that PWE may be reluctant to report seizures to their physician in order to avoid loss of driving privileges [24,25]. Given the strict driving restriction in China, no driving patients reported their disease to the police or to the department of transportation in our previous study [8]. Patients in present study may afraid to admit seizure-related MVA for fear of punishment which may cause under-

reporting; more studies based on police reports, hospital records, and medical databases are needed to explore seizure-related MVA in future research.

5. Conclusion

This study indicates that a significant number of patients with epilepsy drive illegally in China and a proportion of patients even experienced seizure-related MVA. A longer seizure-free interval suggests a compromised risk of seizure-related MVA. However, while driving restrictions in China ban all PWE from driving, doctors should be aware that PWE may still drive, and there remains a risk for crashing in patients with a seizure-free interval for more than two years.

Conflict of interest

There are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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