Original Article

Bicycle-related traumatic injuries: a retrospective study during COVID-19 pandemic

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BACKGROUND: This study aimed to review bicycle-related injuries during the COVID-19 pandemic to assist with reinforcement or implementation of new policies for injury prevention.

METHODS: This is a retrospective descriptive analysis of injuries sustained during cycling for patients 18 years old and above who presented to Singapore General Hospital from January to June 2021. Medical records were reviewed and consolidated. Descriptive analyses were used to summarize patient characteristics, and differences in characteristics subgrouped by triage acuity and discharge status were analyzed.

RESULTS: The study included 272 patients with a mean age of 43 years and a male predominance (71.7%). Most presented without referrals (88.2%) and were not conveyed by ambulances (70.6%). Based on acuity category, there were 24 (8.8%) Priority 1 (P1) patients with 7 trauma activations, 174 (64.0%) and 74 (27.2%) P2 and P3 patients respectively. The most common injuries were fractures (34.2%), followed by superficial abrasion/contusion (29.4%) and laceration/wound (19.1%). Thirteen (4.8%) patients experienced head injury and 85 patients (31.3%) were documented to be wearing a helmet. The majority occurred on the roads as traffic accidents (32.7%). Forty-two patients (15.4%) were admitted with a mean length of stay of 4.1 d and 17 (6.3%) undergone surgical procedures. Out of 214 (78.7%) discharged patients, no re-attendances or mortality were observed. In the subgroup analysis, higher acuity patients were generally older, with higher proportions of head injuries leading to admission.

CONCLUSION: Our study highlights significant morbidities in bicycle-related injuries. There is also a high proportion of fractures in the young healthy male population. Injury prevention is paramount and we propose emphasizing helmet use and road user safety.

KEYWORDS: Cycling; Injuries; Emergency department

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INTRODUCTION

Cycling is not only a popular recreational activity but also a means of transportation with many health and environmental benefits. Road safety has therefore become a great concern for all users in view of the surge in cycling in Singapore during the COVID-19 period, as evidenced by an increase in ridership from bicycle rentals and increased transactions at shops. Prevalence of bicycle injuries had been increasing before COVID-19[1,2] and further increased during the COVID-19 pandemic given its soaring popularity in view of the lockdown with cancellation of all social activities.[3,4] Based on Centers for Disease Control and Prevention (CDC) data, adults aged 55–69 years have the highest bicycle mortality in urban areas with a male predominance, and the younger group has the highest rate of bicycle-related injuries treated in emergency departments (EDs).[5] According to the Singapore annual traffic statistics in 2021, there were 774 casualties, including 11 mortalities.[6] The number of casualties increased by 36% compared to previous year and was the highest over the period from 2008 to 2021. The burden of cycling injuries can be significant,

with potential long-term sequelae not only to the patients but also to the society. The average injury severity score of cycling collision was higher than the overall trauma cohort in Ireland.[7] Among the bicycle injuries, previous studies also cited about 5% and 16%–25% suffer mortality and significant morbidity respectively.[2,8,9]

Studies in a Singapore pediatric ED have shown that there could be injuries resulting in significant morbidities.[2,10] However, no study in the adult population has characterized the type of injuries cyclist sustained during the COVID-19 pandemic. A study by Kwan et al[11] overlapped slightly with the COVID-19 pandemic (August 2018 to December 2020) and showed an increasing trend in monthly attendance of cycling injuries. The only other study conducted in the adult ED compared the use of helmet for bicycle-related trauma between 2004 and 2005.[12] Helmet use was demonstrated to reduce mortality.[7,12] A survey of Singaporean cyclists in 2017 revealed safety concerns, lack of infrastructure and lack of rules.[13] The Active Mobility Act came into force in 2018 and mandated the use of helmet. It also included road safety guidelines including a maximum size of 5 cyclists for group cycling.

This study aimed to review the injury patterns of bicyclists during the COVID-19 period and their significance. We hypothesize that an increase in helmet use leads to a reduction in morbidity and mortality. This study aimed to identify areas and gaps to improve injury prevention especially for recreational cycling.

METHODS

Study setting

This was a retrospective observational analysis of bicycle-related injuries in patients who presented to Singapore General Hospital Emergency Department during COVID-19 pandemic with a 6-month study period from January 2021 to June 2021. Patients below 18 years old and those who were pregnant were excluded. Singapore General Hospital is Singapore's oldest and largest hospital with level 1 trauma capability, and the current ED was built in 1977, with several stages of upgrading.[13] This study was approved by the SingHealth Centralized Institutional Review Board (CIRB 2021/2784).

Study design

Medical records were reviewed and the information was extracted into Microsoft Excel. Variables included demographic details (gender, age, race); cycling injury circumstances (diagnosis, mechanism, date of incident, time of incident, place of incident, helmet use); and emergency visit details (triage acuity, referral source, ambulance case) and disposition were collected. Triage acuity are categorized based on Patient Acuity Category Scale categories into Priority 1 (P1) which are attended to immediately in Resuscitation area, while Priority 2 (P2) for major emergencies who are usually non-ambulant and Priority 3 (P3) for minor emergencies with ambulatory patients.[14] If the patient was admitted, the length of stay and number of procedures or operations performed were recoded. If the patient was discharged, any specialist outpatient referrals were recorded.

Statistical analysis

Categorical variables were described using frequencies (percentages) and continuous variables were described using means with standard deviations (SD) or medians with interquartile ranges (IQR). Differences in patient characteristics by triage acuity and whether patients were admitted or discharged were compared using appropriate tests such as Pearson's Chi-square test, one-way ANOVA, Kruskal Wallis test and Wilcoxon rank-sum test. A two-sided *P*-value less than 0.05 indicated statistical significance. Analyses were performed using Stata 17 (StataCorp., USA).

RESULTS

Study population and demographics

A total of 272 patients were included in this study. There were 4 cyclists which came to ED twice for separate injuries and were treated as separate cases. The median age of the study population was 42 years old, and the majority of the participants were male (71.7%) (Table 1).

Patterns of injuries and circumstances of injuries

The most common injuries were fractures (34.2%), abrasion/contusion (29.4%) and lacerations/wounds (19.1%). The injuries commonly occurred at night (35.3%), from 7 pm to 7 am, and 37.5% presented on weekends compared to weekdays (62.5%). Assuming an equal proportion of each day of the week, there is a preponderance of injuries that occur on weekends (2 out of 7 days corresponds to 28.6%). Injuries occurred mostly in public areas (30.9%) and roads (32.7%). The use of helmet documented was present in 31.3% of our study population, with rest of majority not documented (57.7%) and 11.0% not wearing any helmet.

Among our 93 patients with fractures, 18 patients

(19.3%) required admission, 8 patients refused admission, and the rest were followed up with outpatient orthopedic specialist. Two-thirds of those admitted (12/18) required a procedure—7 patients underwent 1 operation, while 5 patients underwent 2 operations.

Table 1. Demographics and characteristics of study population, *n* (%)

Variables	Results
Demographics	
Gender	
Female	77 (28.3)
Male	195 (71.7)
Age, years, mean±SD	43.3±15.7
Race	
Chinese	173 (63.6)
Malay	23 (8.5)
Indian	22 (8.0)
Caucasian	23 (8.5)
Others	31 (11.4)
Injuries	
Head injury	13 (4.8)
Abdominal injuries	3 (1.1)
Fracture	93 (34.2)
Dislocation	11 (4.0)
Laceration / wound	52 (19.1)
Abrasion / contusion	80 (29.4)
Musculoskeletal pain	39 (14.3)
Non-trauma	4 (1.5)
Circumstances of injury	
Injury time	
Morning (7 am–12 pm)	56 (20.6)
Afternoon (12 pm–7 pm)	57 (20.9)
Night (7 pm–7 am)	96 (35.3)
Not documented	63 (23.2)
Day of presentation	
Weekends (Sat, Sun)	102 (37.5)
Weekdays	170 (62.5)
Place of injury	
Public areas	84 (30.9)
Road	89 (32.7)
Recreational / Sports area	23 (8.4)
Workplace	4 (1.5)
Home / Residential institution	3 (1.1)
Playground	1 (0.4)
Not documented	68 (25.0)
Helmet use	
Yes	85 (31.3)
No	30 (11.0)
Not documented	157 (57.7)
Emergency visit	
Triage acuity	
P1	24 (8.8)
P2	174 (64.0)
P3	74 (27.2)
Referral source	
Self	240 (88.2)
Polyclinic / General practitioner	29 (10.7)
Others (police, hospital)	3 (1.1)
Ambulance	
Non-ambulance	192 (70.6)
Ambulance	80 (29.4)
Outcome	
ED disposition	
Admitted	42 (15.4)
Discharged against medical advice	16 (5.9)
Discharged	214 (78.7)
Admitting discipline	
Medical	6 (2.2)
Surgical	36 (13.2)
Procedure	17 (6.3)
n=1	12
n=2	5
Length of stay, d, median (IQR)	2 (2–5)

SD: standard deviation; IQR: interquartile range; P1: Priority 1; ED: emergency department

Emergency visits and outcomes

Most injuries were triaged as P2 (64.0%), followed by P3 (27.2%), with a small percentage (8.8%) triaged as P1. Among the 24 cyclists triaged as P1, there were 7 trauma team activations. Four of them were activated due to a high-risk mechanism, while the remaining three were activated due to the location of the injuries (concerns for intra-abdominal, spinal, or intracranial injury). Most cyclists were brought without an ambulance (70.6%) and came on their own without a referral (88.2%). While the majority of the cyclists were discharged (78.7%), 16 cyclists (5.9%) were discharged against medical advice, and 42 were admitted (15.4%). Thirty-six patients were admitted to surgical discipline, and 17 required a procedure or operation. The median length of stay was 2 d (IQR 2–5 d). Among the 16 cyclists who were discharged against medical advice, there were two P1 cases and both were trauma team activated. One was activated because of mechanism of injury (collision of the car) and had main injury of possible occult hand fracture. The other was activated for concerns of spinal injury and had main elbow contusion injury.

Subgroup analysis of triage acuity

Table 2 compared the study population in three groups with different triage acuity. In terms of demographics, there was no statistically significant difference in gender, race or age (P=0.93, P=0.32, P=0.06, respectively). However, patients with higher acuity were older than those with lower acuity (P1 and P2, mean age 44.7 years old; P3 mean age 39.6 years old). Among the injuries, cyclists with dislocation injuries were more likely to have higher triage acuity (P=0.004). There was no significant association between injury severity and injury time, place of injury or use of helmet (P=0.76, P=0.94, P=0.23, respectively). All P1 patients presented by themselves without referral and the majority (66.7%) came via ambulance. Last, for disposition, a significant majority of patients with higher triage acuity were admitted (P1 50.0%, P2 14.9%, P3 5.4%, P<0.001) compared to patients with lower triage acuity. There was no significant difference between triage acuity and admitting discipline, number of procedures or length of stay (P=0.99, P=0.17, P=0.86, respectively).

Subgroup analysis of disposition

We compared the data between cyclists who were admitted and those who were discharged, as shown in Table 3. Even though statistical significance was not demonstrated, the median age of cyclists admitted

(45.5 IQR [32–59]) was higher than those who were discharged (40 IQR [29–54]). There was a significantly higher proportion of head injuries in patients who were admitted than in those who were discharged (P=0.03). In contrast, patient with musculoskeletal pain was more likely to be discharged than admitted (P=0.01). Intuitively, patients with higher triage acuity and those who came via ambulance were more common among those admitted than among those discharged (P<0.001 for both). There was no significant difference between

Table 2. Comparison between triage acuity groups, *n* (%)

Characteristics	Triage acuity			*P*-value*
	P1 (*n*=24)	P2 (*n*=174)	P3 (*n*=74)	
Gender				0.93
Female	6 (25.0)	50 (28.7)	21 (28.4)	
Male	18 (75.0)	124 (71.3)	53 (71.6)	
Age, years, mean±SD	44.7±15.6	44.7±15.6	39.6±15.4	0.06
Race				0.32
Chinese	18 (75.0)	110 (63.2)	45 (60.8)	
Malay	3 (12.5)	13 (7.5)	7 (9.5)	
Indian	1 (4.2)	13 (7.5)	8 (10.8)	
Caucasian	0 (0.0)	20 (11.5)	3 (4.1)	
Others	2 (8.3)	18 (10.3)	11 (14.9)	
Injuries				
Head injury	2 (8.3)	10 (5.8)	1 (1.4)	0.17
Abdominal injuries	1 (4.2)	1 (0.6)	1 (1.4)	0.15
Fracture	9 (37.5)	65 (37.4)	19 (25.7)	0.19
Dislocation	4 (16.7)	7 (4.0)	0 (0.0)	0.004
Laceration / wound	3 (12.5)	31 (17.8)	18 (24.3)	0.34
Abrasion / contusion	6 (25.0)	52 (29.9)	24 (32.4)	0.78
Musculoskeletal pain	2 (8.3)	25 (14.4)	12 (16.2)	0.69
Non-trauma	1 (4.2)	2 (1.2)	1 (1.4)	0.37
Circumstances of injury				
Injury time				0.76
Morning (7 am–12 pm)	4 (16.7)	37 (21.3)	15 (20.3)	
Afternoon (12 pm–7 pm)	7 (29.2)	37 (21.3)	13 (17.6)	
Night (7 pm–7 am)	13 (54.2)	63 (36.2)	20 (27.0)	
Not documented	0 (0.0)	37 (21.3)	26 (35.1)	
Day of presentation				0.32
Weekends (Sat, Sun)	9 (37.5)	60 (34.5)	33 (44.6)	
Weekdays	15 (62.5)	114 (65.5)	41 (55.4)	
Place of injury				0.94
Public areas	8 (33.3)	54 (31.0)	22 (29.7)	
Road	12 (50.0)	59 (33.9)	18 (24.3)	
Recreational / Sports area	1 (4.2)	17 (9.8)	5 (6.8)	
Workplace	0 (0.0)	3 (1.7)	1 (1.4)	
Home/residential institution	0 (0.0)	2 (1.2)	1 (1.4)	
Playground	0 (0.0)	1 (0.6)	0 (0.0)	
Not documented	3 (12.5)	38 (21.8)	27 (36.5)	
Helmet use				0.23
Yes	13 (54.2)	53 (30.5)	19 (25.7)	
No	2 (8.3)	24 (13.8)	4 (5.4)	
Not documented	9 (37.5)	97 (55.8)	51 (68.9)	
Emergency visit				
Referral source				0.02
Self	24 (100.0)	158 (90.8)	58 (78.4)	
Polyclinic / General practitioner	0 (0.0)	15 (8.6)	14 (18.9)	
Others (police, hospital)	0 (0.0)	1 (0.6)	2 (2.7)	
Ambulance				<0.001
Non-ambulance	8 (33.3)	117 (67.2)	67 (90.5)	
Ambulance	16 (66.7)	57 (32.8)	7 (9.5)	
Outcome				
ED disposition				<0.001
Admitted	12 (50.0)	26 (14.9)	4 (5.4)	
Discharged against medical advice	2 (8.3)	11 (6.3)	3 (4.1)	
Discharged	10 (41.7)	137 (78.7)	67 (90.5)	
Admitting discipline				0.99
Medical	2 (16.7)	4 (15.4)	0 (0.0)	
Surgical	10 (83.3)	22 (84.6)	4 (100.0)	
Procedure				0.17
No procedure done	22 (91.7)	162 (93.1)	71 (96.0)	
1 procedure done	0 (0.0)	9 (5.2)	3 (4.1)	
2 procedures done	2 (8.3)	3 (1.7)	0 (0.0)	
Length of stay, d, median (IQR)	2 (1.5 – 4)	2.5 (2 – 5)	3.5 (1 – 8)	0.86

*Where relevant, data which were not documented was excluded from the *P*-value calculation. SD: standard deviation; IQR: interquartile range; P1: Priority 1; ED: emergency department

the two groups in terms of the circumstances of injuries: day of presentation, place of injury, or injury time (P=0.62, P=0.76, P=0.80, respectively).

DISCUSSION

During the COVID-19 pandemic, there was a paucity of traumatic injuries sustained by adult bicyclists despite the rise in its popularity. The growth in cycling represents an increase in physical activities but also opens opportunities for a greater number of injuries attributed to either the cyclists themselves or their environment. To improve their safety profiles, the government has been actively designing and planning bicycle-friendly urban areas as well as implementing traffic codes of conduct. We hope to evaluate some common injuries with the goal of providing further advice on protection and prevention.

The characteristics of our study population of cycling injuries are similar to those of other studies. Our mean age of 42 years was similar to that in international studies on cycling injuries.[3,15] Locally, it is slightly younger than the median age of the study population reported by Kwan et al (48 years old).[11] It is slightly older when compared to the earlier local studies reviewing cycling injuries in 2004–2005 (median age 30–32 years old) by Heng et al[12] and injuries caused by personal mobility devices (PMDs) and electric bicycles later in 2016 (mean age 32 years old) by Cha et al.[16] There may be a trend towards older age group in terms of injury patterns as our local population age and more efforts on active aging are

Table 3. Comparison between admitted and discharged cyclists, *n* (%)

Characteristics	Admitted (n=42)	Discharged (n=214)	P-value*
Gender			0.29
Female	9 (21.4)	63 (29.4)	
Male	33 (78.6)	151 (70.6)	
Age, years, median (IQR)	45.5 (32–59)	40 (29–54)	0.15
Race			0.77
Chinese	30 (71.4)	135 (63.1)	
Malay	2 (4.8)	18 (8.4)	
Indian	4 (9.5)	17 (7.9)	
Caucasian	3 (7.1)	16 (7.5)	
Others	3 (7.1)	28 (13.1)	
Injuries			
Head injury	5 (11.9)	8 (3.7)	0.03
Abdominal injuries	2 (4.8)	1 (0.5)	0.07
Fracture	18 (42.9)	67 (31.3)	0.15
Dislocation	3 (7.1)	7 (3.3)	0.22
Laceration / wound	12 (28.6)	37 (17.3)	0.09
Abrasion / contusion	9 (21.4)	69 (32.2)	0.16
Musculoskeletal pain	1 (2.4)	37 (17.3)	0.01
Injury time			0.80
Morning (7 am–12 pm)	9 (21.4)	40 (18.7)	
Afternoon (12 pm–7 pm)	13 (31.0)	42 (19.6)	
Night (7 pm–7 am)	18 (42.9)	75 (35.1)	
Not documented	2 (4.8)	57 (26.6)	
Place of injury			0.76
Public areas	11 (26.2)	66 (30.8)	
Road	16 (38.1)	69 (32.2)	
Recreational / Sports area	3 (7.1)	20 (9.4)	
Workplace	1 (2.4)	2 (0.9)	
Home / Residential institution	0 (0.0)	3 (1.4)	
Playground	0 (0.0)	1 (0.5)	
Not documented	11 (26.2)	53 (24.8)	
Day of presentation			0.62
Weekends (Sat, Sun)	17 (40.5)	78 (36.5)	
Weekdays	25 (59.5)	136 (63.6)	
Helmet use			0.59
Yes	14 (33.3)	66 (30.8)	
No	6 (14.3)	21 (9.8)	
Not documented	22 (52.4)	127 (59.4)	
Referral source			0.22
Self	39 (92.9)	187 (87.4)	
Polyclinic / General practitioner	2 (4.8)	25 (11.7)	
Others (police, hospital)	1 (2.4)	2 (0.9)	
Triage acuity			<0.001
P1	12 (28.6)	10 (4.7)	
P2	26 (61.9)	137 (64.0)	
P3	4 (9.5)	67 (31.3)	
Ambulance			<0.001
Non-ambulance	16 (38.1)	165 (77.1)	
Ambulance	26 (61.9)	49 (22.9)	

*Where relevant, data which were not documented was excluded from the P-value calculation. IQR: interquartile range; P1: Priority 1.

promoted. Our study also showed that cyclists who were admitted tended to be older with higher triage acuity. Education on road safety among older cyclists should be emphasized and further improved.[17] The proportion of patients requiring admission in our study population (15.4%) is also similar to that in studies by Eid et al (15.5%) in Arab[18] and Cha et al (13.9%) on local injuries caused by PMDs and electric bicycles.[16] This is also comparable with the local pediatric population citing 16.8% requiring admission in 2011–2015, but higher than that in another study on non-motorized active mobility devices in 2016–2020, which reported a 0.42% admission rate. The admission rate of the similar local ED study by Kwan et al was higher (57.9%) which may be due to the older study population (median age 48 years) with higher triage acuity (16.4% were P1).[11] The lengths of stay reported by Kwan et al and other studies were also similar to ours, ranging from 2 to 7 d.

During the 6-month study period, there was no mortality, but the study demonstrated significant morbidity with the most common injury being fractures (*n*=93, 34.2%). Fractures were also the common injuries in another study on cycling-related injuries in Norway, albeit with greater incidence of 65%.[15] Faulkner et al[3] also found that fractures were the most common injuries requiring orthopedic intervention, along with an increase in the need for orthopedic intervention during COVID-19. In contrast, in the local pediatric study population, the most common injuries were superficial injuries (46.1%) followed by fractures (19.2%).[2] This highlights that in the adult population, cycling can potentially inflict more significant morbidities, as demonstrated by the fracture burdens and orthopedic referrals, even though it may not be acutely life-threatening. Particularly in younger to middle-aged healthy males, they could in turn impede desirable physical activities and perhaps elite training, as long-term sequelae may occur as a result of the injuries.

In our study, subgroup analysis revealed that head injuries were associated with the need for admission. The use of helmet has been shown to be a single cost-effective measure to prevent injuries. There is clear evidence on the linkage between poor compliance with helmet use and significant morbidities in the literature.[19] Helmet use in our study population was 31.3%. This finding improved from a previous local study in 2004-2005, where 10.5% of the population wore helmet[12] but a recent local ED study by Kwan et al also shown low helmet use at 18.7%.[11] Recent international data cited rates of helmet use ranging mostly from 41% to 62%,[4,20–21] with the exception of one study by Benhamed et al citing 30.7%.[22] Greater efforts are needed to increase awareness of wearing helmet as it is compulsory by law in Singapore. Stricter enforcement of legislative policy for helmet use together with other protective apparels, such as proper footwear, should be considered. Without adequate gears, the road poses more threat to the bicyclists. Qualitative analysis of the barriers and attitudes towards helmet use specifically may be useful to target these efforts in our Asian context.[23,24]

Our study highlights that a majority of the injuries occurred on roads and in public areas and between 7 pm and 7 am. Further efforts to improve road user safety in these areas include clear, bright signage and dedicated lanes. During night time cycling, there can be increased awareness of wearing brightly colored helmet and gears, reflective lights, and improved infrastructure with road lightings and directions. Since our data were collected during the COVID-19 lockdown, i.e. less competitive traffic, henceforth as Singapore and the world resumed normalcy, the amount of traffic will likely increase, so it is even more important to ensure road safety for all users.

Limitations

Inherent to all retrospective studies, the information available is dependent on accurate documentation of electronic records. Some important information was not documented including the use of helmet, the exact location and the time of injury. Future prospective research can collect variables such as the activation of trauma team, injury severity scores, injury mechanisms and circumstances including helmet usage, speed, mileages, etc. Finally, those injured bicyclists who had seek medical attention at primary care or other hospitals and those who pronounced dead at scene were also not included in our study.

CONCLUSION

Our study highlights significant morbidities in bicycle-related injuries in Singapore during the COVID-19 pandemic. There is also high proportion of fractures in the young healthy male population, which could decrease productivity at work. Injury prevention would be paramount as only 31.3% were compliant with helmet use; therefore, we propose more rigorous education and enforcement on proper road user safety, especially when traffic is expected to increase as Singapore returns to normalcy from COVID-19 pandemic. Future directions could include further data

points such as trauma activation, injury severity scores; and analyze the characteristics of inpatient stay.

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Ethical approval: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the *Declaration of Helsinki* (as revised in 2013). The study was approved by the SingHealth Centralized Institutional Review Board (CIRB 2021/2784) and a waiver of consent for this retrospective analysis was obtained.

Conflicts of interest: All authors have completed the ICMJE uniform disclosure form. The authors have no conflicts of interest to declare.

Author contributions: Conception and design: YHZ, FL; Administrative support: JEJS, YHZ, GHL; Provision of study materials or patients: YHZ; Collection and assembly of data: JEJS; Data analysis and interpretation: JEJS, YHZ, GHL; Manuscript writing: All authors; Final approval of manuscript: All authors.

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