Characterization and Prevention of Burn Caused by Electrical Bicycle Battery Charging (BEBBC): Results from a 7-year Experience

Xiqiao Wang  
Ruijin Hospital

Ming Tian  
Ruijin Hospital

Jianlin Hu  
Ruijin Hospital

Mu Sun  
Ruijin Hospital

Liqiang Zheng  
Shanghai Jiao Tong University

Liang Qiao  
Ruijin Hospital

Yan Liu  
Ruijin Hospital

Bo Yuan  
hiyuanbo2002@163.com  
Ruijin Hospital

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Abstract

With the exponential increase in express deliveries over the recent years in China, the battery used for electrical bicycle, is yet hazardous and sometimes leads to fire disaster while charging. The typical burn caused by electrical bicycle battery charging (BEBBC) has remarkably increased. A retrospective chart review of patient associated with BEBBC collected in department of Burn in Rui Jin Hospital between January 2015 and December 2021 were performed. 63 BEBBC and 1412 flame burn patients were collected in this study. 56 of the 63 cases (88.89%) occurred while sleeping at night. Most of BEBBC incidents occurred in a densely populated residency and presented with higher incidence of group burn (58.73% vs 7.97%, \( P = 0.0001 \)). The average age of nonlocal in BEBBC was significantly younger than that of local (33.69±1.91 vs 54.23±4.15 years, \( P = 0.0001 \)). BEBBC also had higher mortality in comparison with that of flame burn (11.11% vs 3.40%, \( P = 0.0016 \)). The rising incidence of BEBBC calls for more attention because of its higher mortality and high impact on society. Legislation, popular science propaganda, or treatment improvement on controlling infection of respiratory tract and bacteria translocation of gastrointestinal tract might increase cure rate and reduce mortality in BEBBC.

Introduction

In most of burn centers in China, scalds are the dominating cause of pediatric burns while flame are the primary cause in adult patients\(^1\). Compared with the scald burn, flame burn usually has higher mortality, longer length of stay and subsequently more medical expenses, putting a huge burden on patients and society\(^2\). In 2016, promoted by the boom in China’s online retail business, the volume of China’s express deliveries comprised of about 60% of the global volume\(^3\). From the report of China Express Association, the numbers of delivery personnel employed in 2019 has increased to over 3.2 million. More and more people are removed from the small villages, towns, or cities to the big cities such as Beijing, Shanghai, Guangzhou and joined the queue as deliverymen. Their main tool for transportation, the electrical bicycle remains an indispensable equipment for their living. Consequently, the incidence of flame burn caused by electrical bicycle battery charging (BEBBC) has shown remarkable increase over the recent years. In this study, we have retrospectively investigated this type of flame burn with aim to analyze its clinical characteristics and features, hence hoping to research effective methods to prevent its occurrence.

Methods

STUDY SETTING AND DESIGN

This study was performed after the study protocol was approved by the Institutional Research Ethics Board (IREB) of Rui Jin Hospital, Shanghai Jiao Tong University School of Medicine. A waiver of the informed consent requirement was approved by the IREB due to the retrospective nature of the study. The clinical information of the flame burn and BEBBC cases who were admitted to the department of burn in Rui Jin Hospital between January 2015 and December 2021 were reviewed and analyzed. All experiments were performed in accordance with relevant guidelines and regulations.
DATA COLLECTION

The following demographics and clinical variables were collected: 1) the patient basic information including age, sex, BMI, occupation, household registration, concomitant diseases before injury, 2) and factors with accidents such as admission by group or single person incidence, time of fire occurrence, 3) diagnosis including burn lesion size and depth, combined with inhalation injury or other complicated injury, laboratory tests, treatment such as blood transfusion, surgery, feeding and defecation, infection and outcomes etc.

DATA ANALYSIS

Continuous data were presented as mean ± Standard Error of Mean (SEM) and compared using Student’s t-test. Categorical data were presented as number (percentage) and compared using the chi-square test. P<0.05 was considered statistically significant. All statistical analyses were conducted using GraphPad Prism (Version 6.01).

Results

Between January 2015 and December 2021, 1475 burn cases who were admitted to department of burn in Rui Jin Hospital were collected and analyzed. Among the 1475 cases, 63 burn cases were BEBBC while 1412 cases were other flame burn (hereinafter to be referred as “flame burn”) patients (Table 1).

The incidence of BEBBC cases and its proportion in flame burn cases have elevated in the recent years (Figure 1A and B). In terms of the seasonal distribution, there was no evident disparity among spring, summer, autumn and winter (P=0.5603).

Most of fire disaster in BEBBC happened when people were asleep. About 88.89% of the BEBBC cases occurred between 9 pm and 7 am. 7 people chose to jump off the building and 3 of them were diagnosed with lumbar, humerus and ulnae, or metacarpal fractures. Other associated injury included 1 case with brief coma. After inquiry, it was found that the patient with brief coma was inebriated before the injury. Besides, 2 cases with corneal injury and 4 cases with soft tissue contusion.

Most of BEBBC happened in a higher density living environment which resulted in a higher presentation of group burns (The definition of group burn is number of patients who involved in the same fire disaster and admitted to emergency simultaneously are no lesser than 2) compared with flame burn (58.73% vs 8.29%, P 0.0001) (Figure 2). The average number of patients in each incident was 1.95±0.12. The median was 2 and the maximum was 4.

The composition of BEBBC patients in regard with household registration was classified into local and nonlocal. There were 44 males and 19 females, and no gender difference between the local and nonlocal. The average age of BEBBC patients was 38.08±2.0 years old, which was evidently younger than that of flame burn (43.26±0.51 years old, P=0.0340) (Table 1). Moreover, the average age of nonlocal was significantly younger than that of local in BEBBC(33.69±1.91 vs 54.23±4.15 years, P 0.0001) (Figure 3).
43 patients (accounting for 68.25% of BEBBC and 86% in nonlocal group), made money from odd jobs such as delivery man, shop assistant, or street vendor. There were 3 children as their family members and the average age, burn size, and full-thickness area of them was 3.33±0.58 years, 14.67±6.11% TBSA, 2.33±2.31% TBSA, respectively. All of the children involved in this study had to undergo surgery and the average of hospital stay was 23.5±6.61 days. 8 patients (61.54% in the local group) were retired or unemployed, majority of them were low-income population.

The mean BMI index was 23.98±4.42 kg/m². The number of obese with BMI≥30 was 6, about 9.5% in total, who showed to have higher incidence with chronic diseases such as hypertension, cardiopathy, or fatty liver. However, there was no significant correlation between BMI and inhalation injury incidence, or mortality (P=0.38, 0.53, respectively).

The past medical history showed about 73.02% patients were healthy with no chronic diseases. 6 people had hypertension and 2 of them had coronary or valvular heart diseases, or 1 of them had cerebral infarction history, 3 people had nasal-sinusitis, hearing disorder or parotid gland cyst and 2 people had gallstone. 3 people previously had operation for removing parotid gland cyst and appendix, cesarean, or sterilization.

The average of burn size and full-thickness burn area in BEBBC was 26.41±3.46% TBSA, 10.24±2.19% TBSA, respectively, which were no significantly different from the flame burn with 24.65±0.65% TBSA and 12.21±0.43% TBSA (P=0.5792, P=0.3398). Number of people with burn area over 30% in BEBBC was 20 and the average of burn size was 61.40±4.64% TBSA. Accordingly, there were 435 people and 55.45±1.03% TBSA in the flame burn group. Regarding the ratio of severe burn in two populations, there was no statistical difference (P=0.87). The largest burn size in BEBBC group was 95% TBSA and the minimal burn size was 0, implying patients were solely diagnosed with inhalation injury without skin lesion.

49 patients in BEBBC were diagnosed with inhalation injury. In comparison with the flame burn group, the incidence of inhalation injury in the BEBBC group was dramatically higher (77.78% vs 30.88%, P 0.0001). Among them, 14 underwent tracheotomy. 2 patients were treated with tracheal intubation on the first or second day after injury due to the acute respiratory tract swelling and the tracheal cannula was removed within the following 3~5 days.

The BEBBC group also had higher mortality in comparison with flame burn group (11.11% vs 3.40%, P=0.0016)(Figure 4). The main cause of mortality were multiple organ dysfunction syndrome (MODS) in 4 patients, acute respiratory failure after severe inhalation injury in 1 patient, and ventricular fibrillation in 1 patient. One patient’s family insisted to transfer to local hospital and died with acute renal failure on the second day (Table 2). The main cause of mortality in flame burn were also summarized in Table 2. There was no significant difference between them. Also, the characteristics of death in both groups were analysed. A qSOFA value of ≥2 and a rBaux score 140 are considered high risk for predicting prognosis in burn patients. However, both groups showed no evident difference in view of qSOFA values or rBaux
scores. The same situation existed in terms of ratio of BSI (blood stream infection) with CRKP (carbapenem-resistant Klebsiella pneumoniae), duration of mechanical ventilation, the incidence of pneumonia as well as length of hospital stay between two groups (Table 3).

Considering the inhalation injury, facial or cervical burn involved, fasting was a basic treatment in order to avoid the vomiting and reduce the risk for aspiration. 53 patients, (accounting for 84.13% of BEBBC), had their meals after 1 day since injury. The mean time of feeding post injury was 1.69±1.24 days. The time for first defecation after injury was also observed. The mean time for defecation onset was 3.74±2.62 days. Interestingly, duration of first defecation after injury was evidently longer in the deceased people than that of survivors (P=0.0015 or P 0.0001) (Figure 5).

The average of hospital stay was 23.98±3.03 days in BEBBC cases, which was no significantly different from that of flame burn group. During this time, 42 patients had undergone surgery, mainly including debridement and skin grafting procedures. The average number of operations was 2±1 times. There was no difference between BEBBC and flame burn in terms of number of surgical patients.

**Discussion**

As a special type of flame burn, there was no difference between BEBBC and flame burn in terms of pediatrics burn proportion, gender ratio, total burn size or full thickness burn size, length of hospital stay or surgical intervention. However, the mortality incidence in BEBBC was 3.27 times of flame burn, indicating the higher mortality of BEBBC (11.11%) should be handled seriously. In developed countries such as Canada, the mortality has decreased from 11.3% to 2.8% between 1976 and 2015\(^2\). In China, the mortality of people aged over 60 years was 0.9% and flame was the most common cause\(^5\). Another study based on 6,325 burn patients also showed the mortality was 0.9% and risk factors included full-thickness burns, larger TBSA and older age\(^6\). There was no different between BEBBC and flame burn regarding total burn size and full thickness burn area. Also, in comparison with the flame burn, the average age of patients in BEBBC was 38.08±2.0 years, a younger population. In addition, about 73.02% patients were healthy and without underlying diseases. However, the inhalation injury is an independent risk factor for mortality in burns\(^7\). The inhalation injury incidence in BEBBC was 2.52 times of flame burn. 16 of them underwent tracheotomy or intubation due to acute respiratory failure. The artificial airway and mechanical ventilation if applied will place patients at a high risk for ventilator-associated pneumonia, which will get worse in combination with inhalation injury\(^8\).

To reduce the incidence of BEBBC, the crucial elements including susceptible population (WHO), frequently occurring time periods (WHEN) and places of occurrence (WHERE) are needed to be studied.

The incidence and proportion of BEBBC in flame burn has gradually increased. This trend has a close connection with the social changes in the latest years. Express delivery industry is booming as the online shopping has become a critical way in Chinese people’s daily life. China’s express delivery volume reached 63 billion pieces in 2019, and the situation in Germany and the United States also predicted to be
double in the next decade\textsuperscript{9}. With the demand of labor force in the express delivery industry, young workforce is gathered from small cities, towns or villages to the metropolis such as Beijing, Shanghai, etc. Considering the composition of patients, the young nonlocal engaging delivery work and elder local people mainly with retired situation were the principal victims, suggesting a community with this people should be the main population needed to be educated in order to avoid BEBBC hazards.

Regarding the occurrence time of BEBBC incidents, about 88.89\% cases happened during bedtime or between 9pm and 7am. In this scenario, the fire disasters often destroy the electric circuit in combination with the dense smoke and people require quick reaction to escape. But sleeping usually delays the time for discovering the fire disaster and the night escape after waking up also becomes difficult. Children tend to be more easier to bear the brunt of harm. Although only 3 children involved in this study, all of them were moderate or severe burn based on the burn lesion size and depth, and treated with couple of surgeries and healed with hypertrophic scar afterwards, which often left a heavy psychological burden on the parents and made them feel sadness and guilt\textsuperscript{10}.

In addition, obesity with body mass index (BMI) \(\geq 30\) were likely to have mobility impairment\textsuperscript{11}. The mean BMI index in this study was 23.98\(\pm\)4.42, and the proportion of obese with BMI\(\geq 30\) was about 9.5\% in total and there was no evident correlation between obesity and worse outcomes, suggesting that the overweight was a insignificant factor in BEBBC based on present small sample size study. However, in view of the obese patients had higher ratio with chronic diseases\textsuperscript{12}, which might complicate the medical treatment in clinical scenario.

In terms of the places where BEBBC happened, a high density living site is frequently involved. Because the young nonlocal engaging delivery or temporary work usually live in lower pay rental housing, where a high density living is most commonly seen. For the convenience of work and travel, they are used to charging electrical bicycles at the first-floor passage. The restricted public corridor, in combination with the solid, flammability waste disposal, where the battery of their electrical bicycles are kept charging, increase fire risks\textsuperscript{13}. The worse is when the fire occurs, the escape way at the first-floor is blocked, which delays the rescue time.

As a public disaster, the news about BEBBC are not uncommon throughout the year. Traditional media such as television, radio, newspaper or social media such as WeChat or Weibo were all used to spread the information widely, which highly impacted on society\textsuperscript{14,15}. Partly because of the contribution of social media serve as a useful adjunct tool to help make public health policies\textsuperscript{16}, the Safety Administrative Regulations of Non-motorized Vehicles in Shanghai has been issued and implemented on May 1\textsuperscript{st} 2021. The non-motorized vehicles charged besides the way for people passing through especially on the first floor is strictly forbidden by this law. Besides, a public charging station for non-motorized vehicle, equipped with surveillance camera, fire auto-alarm, and extinguish system are demanded to build up in community now.
In addition, in order to extend the driving distance and efficiency, the electrical bicycle's batteries are reassembled and readapted by their owners to increase their voltage and output and during the process, they alter the electric circuit and sometimes the load. Usually, the battery is designed for flame retardant and interruption of power supply initiated when fully charged\textsuperscript{17}. However, after the private modification, the security settings are easily overridden and destroyed, which might be the primary causation in BEBBC. Based on this, private modification of battery of electrical bicycle should be strictly prohibited.

The high ratio of group burn in BEBBC led to be paid more attention from the society. The high density living above mentioned easily caused group burn. Herein, the term “massive burn” is not applied because a mass casualty event is defined as a situation wherein the number of patients and the severity of their injuries exceed the capability of the existing facilities to deliver care by routine way\textsuperscript{18}. However, the maximum of patients in BEBBC was 4, which was under the control of our burn unit. Conditions such as the patients was already dead before first aid arrival who were not transferred to hospital, or patients with slightly injury were followed up in the outpatient department instead of admission might be considered. In fact, the above mentioned situations will enlarge the number of group burn patients involved in this study.

Lastly, how to increase the cure rate for BEBBC is also our concern. The primary cause of death in BEBBC was MODS. All of MODS in BEBBC caused by sepsis. There is evidence of pathological organisms cross-colonization between the burn wound and tracheobronchial tree\textsuperscript{19}. Infection of pathogenic associated with mortality in this study was carbapenem-resistant Klebsiella pnermoniae (CRKP), carbapenem-resistant Acinetobacter baumannii (CRAB), carbapenem-resistant Pseudomonas aeruginosa (CRPA). Especially, the incidence of CRKP has been increasing over the latest years. CRKP infection is also an independent risk factor for sepsis burn patients\textsuperscript{20}. Growing evidence shows that intestinal dysbiosis is associated with the development of constipation\textsuperscript{21}. It has been revealed that enteric dysbiosis could promote organ inflammation and injury during sepsis of patients\textsuperscript{22}. In this study, the onset to first defecation after injury was significantly longer in the treatment failure patients compared with that of survivors, suggesting it was a potential prognostic factor in evaluating the outcome. About 84.13% of BEBBC had their meals after 1 day since injury and the mean time of feeding post injury was 1.69±1.24 days. Treatments such as advancing the time of enteral feeding and using laxatives would probably reduce the incidence of bacterial translocation from intestine and infection eventually.

**LIMITATIONS**

The largest limitation of this study was that it was a single burn center study. Although as the biggest burn unit in Shanghai and a center for Shanghai Burn Emergency, most of burn patients were collected in our burn unit. But increasing the number of burn unit and enlarging the BEBBC cases would improve the quality of study and providing more information on policy making, medical treatment modification for reducing BEBBC occurrence and mortality.

**Conclusion**
All in all, owing to the five characteristics in BEBBC, including high incidence at night during bedtime, high incidence in high density residential areas, presentation with group burn cases, showing high impact on society, and leading to high mortality (Figure 6), more attention should be paid to the prevention and management of BEBBC. Legislation, popular science propaganda on high density living community especially those having higher ratio of deliverymen with electrical bicycles including prohibiting battery modification as well as charging in fire passage, or treatment improvement on controlling infection of respiratory tract and bacteria translocation of gastrointestinal tract might increase cure rate and reduce mortality in BEBBC.

Declarations

ACKNOWLEDGEMENTS

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COMPETING INTERESTS

All the authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS

LQ, YL and BY conceived the study and study design. MS and JLH contributed to data acquisition. LQZ and BY conducted data analysis. All authors contributed to the interpretation of the data as well as the manuscript writing, critical review and final revisions. All authors had access to the data, read and approved the version to be published. All authors agreed to be accountable for all aspects of the work.

Data availability

Data is available from Bo Yuan upon reasonable request.

References


19. **Hemdon, D. N.** *Total Burn Care*. Philadelphia, PA: Elsevier, 2018,


### Tables

**Table 1  Clinical information of BEBBC and flame burn**

<table>
<thead>
<tr>
<th>Items</th>
<th>BEBBC (n=63)</th>
<th>Flame burn (n=1412)</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pediatrics burn (Age ≤ 6 years)</td>
<td>3</td>
<td>62</td>
<td>0.8884</td>
</tr>
<tr>
<td>Number of mortalities</td>
<td>7</td>
<td>48</td>
<td><strong>0.0016</strong></td>
</tr>
<tr>
<td>Male to female ratio</td>
<td>2.32 1</td>
<td>2.10 1</td>
<td>0.7841</td>
</tr>
<tr>
<td>Age (years)</td>
<td>38.08±2.0</td>
<td>43.26±0.51</td>
<td><strong>0.0340</strong></td>
</tr>
<tr>
<td>Burn size (% TBSA)</td>
<td>26.41±3.46</td>
<td>24.65±0.65</td>
<td>0.5792</td>
</tr>
<tr>
<td>Full thickness burn (% TBSA)</td>
<td>10.24±2.19</td>
<td>12.21±0.43</td>
<td>0.3398</td>
</tr>
<tr>
<td>Number of Inhalation burn</td>
<td>49</td>
<td>436</td>
<td><strong>0.0001</strong></td>
</tr>
<tr>
<td>Hospital stay (days)</td>
<td>23.98±3.03</td>
<td>22.18±1.05</td>
<td>0.7194</td>
</tr>
<tr>
<td>No. Of surgical patients</td>
<td>42</td>
<td>805</td>
<td>0.1520</td>
</tr>
</tbody>
</table>

**Table 2  Summary of cause of death in BEBBC & Flame burn**
Table 3  Analysis of characteristics of death in BEBBC & Flame burn

<table>
<thead>
<tr>
<th>Items</th>
<th>BEBBC (n=7)</th>
<th>Flame burn (n=48)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>qSOFA score≥2</em></td>
<td>2(28.57%)</td>
<td>16(33.33%)</td>
<td>0.8019</td>
</tr>
<tr>
<td>rBaux score 140</td>
<td>3(42.86%)</td>
<td>30(62.5%)</td>
<td>0.3217</td>
</tr>
<tr>
<td>Cause of death with MODS</td>
<td>4(57.14%)</td>
<td>35(72.92%)</td>
<td>0.3907</td>
</tr>
<tr>
<td>BSI with CRKP</td>
<td>2(28.57%)</td>
<td>16(33.33%)</td>
<td>0.8019</td>
</tr>
<tr>
<td>Duration of mechanical ventilation (d), mean (SEM)</td>
<td>23.00±10.14</td>
<td>19.29±3.24</td>
<td>0.6914</td>
</tr>
<tr>
<td>Pneumonia,n (%)</td>
<td>6(85.71%)</td>
<td>41(85.42%)</td>
<td>0.9834</td>
</tr>
<tr>
<td>LOS (d), mean (SEM)</td>
<td>35.86±14.44</td>
<td>26.15±3.76</td>
<td>0.3875</td>
</tr>
</tbody>
</table>

qSOFA: quick sequential (Sepsis-related) organ failure assessment
MODS: multiple organ dysfunction syndrome

* All of MODS in BEBBC caused by sepsis while 26 of MODS in Flame burn caused by sepsis.

# 1 patient died of acute renal failure in BEBBC while heart failure in Flame burn.
BSI: blood stream infection

CRKP: carbapenem-resistant Klebsiella pneumoniae

LOS: length of stay

**Figures**

**Figure 1**

A  The number of BEBBC

![Graph A: The number of BEBBC over years](image)

B  The ratio of BEBBC in flame burn per year

![Graph B: The ratio of BEBBC in flame burn over years](image)
Figure 1

(A) The number of BEBBC cases from Years 2015-2021  B The ratio of BEBBC in flame burn cases from Years 2015-2021

Figure 2

BEBBC cases presented with higher incidence of group burn
Figure 3

Average age in different populations of BEBBC

Younger population in non-local than that of local in BEBBC
Figure 4

Mortality between groups

P=0.0016

<table>
<thead>
<tr>
<th>Type</th>
<th>BEBBC</th>
<th>Flame burn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival</td>
<td>89%</td>
<td>97%</td>
</tr>
<tr>
<td>Dead</td>
<td>11%</td>
<td>3%</td>
</tr>
</tbody>
</table>

Figure 4

Higher mortality in BEBBC in comparison with that of flame burn
Figure 5

Duration of first defecation after injury

Longer duration of first defecation after injury in the deceased people than that of survivors in BEBBC and flame burn.
Five characteristics of BEBBC