The value of mobile phone videos in increasing the diagnosis accuracy and saving cost of consultation for infant paroxysmal events: a prospective study in China

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**Abstract**

**Objectives:** To investigate the role of mobile phone videos in the diagnosis of paroxysmal events in infancy and the factors that will influence correct diagnosis and then to analyze the cost savings for patients with the videos of paroxysmal events for
online consultation.

**Method:** Clinical data of 12 patients with paroxysmal events were collected for the research. A questionnaire was designed to simulate patients' first visit in outpatient clinic. The investigation was conducted in 6 centers during the pediatric academic conferences. All 452 practitioners present were asked to make a diagnosis by the description of the event from the caregivers, and then they would watch a mobile video of the paroxysmal events and make the diagnoses again. The doctor’s background information including education background, profession, working years, and working hospital level would also be recorded. The costs saved from accurate diagnosis without further need of examination when choosing online consultation were measured.

**Results:** A total of 452 questionnaires were collected in this study, 301 of which met the criteria (66.6%) and were included in the study. The mean amount of correct diagnosis with and without videos was 8.4 and 7.2, respectively. For epileptic seizure, mobile phone videos increased the mean rate of correct diagnosis by 3.9%; for non-epileptic events, the rate increased by 11.5%, and both were statistically different. Pediatric neurologists with longer working years obtained significantly higher correct identification rates, while their working hospital level and education background made no difference. For children patients with paroxysmal events, if they choose online consultation for their first visit, at least $1.28 \times 10^8$ dollars ($8.22 \times 10^8$ yuan) can be saved per year and at least 12.02% of the total cost for correct diagnosis.
Conclusion: This study demonstrated the importance and usefulness for mobile phone videos in clinic, and it will largely help clinicians complete the diagnosis, especially for the non-epileptic events in infants. For patients on their first visit, pediatric neurologists with longer working years are recommended. Online consultation is a better choice for all patients with paroxysmal events and for non-epileptic patients, the underlying saving can be more.

Key words: paroxysmal events, infancy, mobile phone videos, online consultation, China

Introduction

Infants commonly undergo many kinds of paroxysmal events characterized by sudden, mostly short-term involuntary movements involving various parts of the body (1-3). Some of them are epileptic seizure, but the others are non-epileptic seizure due to the immaturity of the central nervous system, pathological, or other non-epileptic reasons (4, 5). Approximately 20%-40% of patients in epilepsy referral centers are diagnosed with paroxysmal non-epileptic events (PNES) (6). Bye et al. (3) reported that PNES are diagnosed in 43% of children who underwent video-electroencephalography (VEEG) monitoring. However, there are inherent difficulties in diagnosis in this population. In fact, many factors may hamper the clinical differential diagnosis (7, 8). First, because of the inability to express themselves, the descriptions of seizure are mostly made by their caregivers who have never been trained to identify seizure types. Thus, these descriptions may be inaccurate or
incomplete(9). Also, lack of video recordings may also contribute to the dilemma of diagnosis(10).

Video-EEG monitoring to obtain an ictal recording plays a central role in the management of paroxysmal events in children(10-13). This method is considered as the golden standard in the differential diagnosis of paroxysmal events(14, 15). The diagnostic accuracy rate of video-EEG monitoring can reach up to 88.0%(16), whereas that of ambulatory EEG is only 67.5%(17). However, paroxysmal events usually occur at home; thus, video-EEG monitoring of paroxysmal events usually fails in clinical settings because of the low ictal frequency. In addition, most centers in China do not have a 24-hour on-call EEG service and appointment means a prolonged waiting time from days to months. In such cases, clinical acumen become the only assistance for clinicians on differential diagnosis(16).

Worse still, in China, the contradiction between the surging number of children and the lack of pediatricians, between the concentrated distribution of high level hospitals, mostly in developed areas, and widespread distribution of patients, many in remote areas, makes it difficult for many patients to get timely diagnosis and follow-up treatment. Except Beijing and Shanghai, the supply and demand ratios of pediatricians are less than 0.80 and there are 191,981 to 198,287 pediatricians in need to meet the service demands(18). An even harsher reality is that for patients in remote areas, their family have to spend a lot on traffic and accommodation before getting diagnosis and treatment. In Shanghai, 56.8% of pediatric patients are non-native(19). For a paroxysmal event, examination and subsequent periodic review also means a lot of
expenses. All of these have greatly exacerbated the issue of “difficulties and high
costs of getting medical services” in China (20).

With the increasing popularity of smart phones worldwide, recording the paroxysmal
event becomes easier. Emma et al. (21) reported that home videos are helpful in aiding
interpretation of ambulatory EEG monitoring. In September 2017, about 1.39 billion
mobile phone subscriptions had been registered in China. (https://www.statista.com/statistics/278204/china-mobile-users-by-month/). This
popularity makes it possible for the patients to record the whole paroxysmal event and
then get online consultation. This has already triggered a new healthcare mode, the
mobile healthcare mode. In this regard, some studies combined the video recording
technology with ambulatory EEG monitoring (22, 23) to explore its value. But there
have been no studies on the value of this model for the diagnosis of infant paroxysmal
events.

The present study aims to identify the value of mobile phone videos on the diagnosis
of paroxysmal events and its potential use for online consultation on helping deal with
the medical services dilemma in China.

**Methods**

This is a prospective study. The trial was conducted in accordance with the
international rules of good clinical practice (GCP). Informed consent was obtained
from each patient’s parents before trial-related procedures were initiated.

**Video selection**
Twelve digital video recordings showing various paroxysmal movements in infants were collected from Chinese PLA General Hospital outpatient from May 2015 to January 2016. The flowchart of choosing the videos is described in figure 1. We also collected video-EEG reports, and the video-EEG was recorded from different centers using 18 scalp electrodes.

All videos were independently presented by the first author to each senior author. Two senior pediatric neurologists analyzed the VEEG findings with the additional relevant clinical data and gave a clinical diagnosis of each event. Events were categorized as epileptic or non-epileptic. When 2 senior reviewers disagreed with the clinical diagnosis of the events, a third reviewer who was blinded to the study would review the video and clinical data and provide a clinical diagnosis. A final clinical diagnosis was given when the third reviewer agreed with one of the senior reviewers. We did not encounter a situation in which all three reviewers could not achieve an agreement.

**Data collection**

We conducted our investigation in 6 centers during the pediatric academic conference, and all doctors present participated in this study. The person responsible for playing the videos was unaware of the diagnosis. The items in the questionnaire included the basic information both doctors and patients prefer to get in online consultation process. Before the investigation, enrolled doctors were informed of the purpose of the study and that all data were anonymous, and then they were asked to complete a short questionnaire entailing their profession (pediatrician/pediatric neurologist), education background, working hospital level (first/secondary/tertiary hospital), and
The process of completing the questionnaire was as follows. First, all the doctors were asked to fill in their basic information. Second, the episode descriptions of the 12 videos were presented to the participating doctors, and then they were asked to judge it as epileptic or non-epileptic events and fill out the form provided. This part also simulates the process of consultation for patients without video recordings. Third, 12 corresponding videos together with the descriptions were presented to the doctors, and they would make their judgment again and fill in another form. This part simulates the process of consultation for patients with video recordings. Fourth, the staff or researchers took back all the forms, and handed over them to the first author. The VEEG reports were not presented to the participating doctors throughout the process. Only completed, writing identifiable questionnaire was eligible for our study.

The cost saved by online consultation and for patients with or without videos were obtained from published articles or government work report, including transportation fee, accommodation fee, loss of wages, and registration fee.

**Data Analysis**

All data were recorded in Epidata and exported to SPSS 24 for statistical analysis. The correct diagnosis rate of each clinical manifestation was calculated, and the difference was compared through Chi-square test and we then drew the ROC curve for each and calculated the area below the curve. On the analysis of the impact of the doctors’ background on diagnosis, we equaled correct diagnosis to 1 and incorrect diagnosis to 0, and then calculated each doctor’s score under the condition of the
existence and nonexistence of videos, and then compared the influence of doctors’ profession, education background, working hospital level, and working years on diagnosis by multiple linear regression analysis. We further analyzed the scores of each physician on the diagnosis of epileptic seizures and non-epileptic seizures with or without videos to analyze the role of the doctor’s background in both cases. The statistical tests presented are two-tailed, and a significance level of $p<0.05$ was used.

All patients, if consulted online for their first visit, can save the cost on transportation, accommodation, and loss of wages. Since there has not been any standard for the charge of online consultation, we here equated the fee with traditional outpatient registration fee, so this fee cannot be saved. Since there has also been no data on the number of children patient with epilepsy and the prevalence of it in different regions of China is different, we first estimated the annual incidence and the total number of new epilepsy patients through related literatures(15, 24-30). Then, we estimated the total number of new patients every year who presented with paroxysmal event and were diagnosed as non-epileptic event according to the ration of epileptic event to non-epileptic event in all paroxysmal events of children(31, 32). Since the proportion of infant patients is not available, so when calculating the total cost saved by bringing videos and choosing online consultation, we extended the age to 9 and thereby calculated the total cost saving for patients under 9 years old nationwide. If the patients have not obtained accurate diagnosis for their first visit, they will have to pay for additional charge on their second visit. Since we will never know how many times
of visit these patients need to get accurate diagnosis, we assume that they could all achieve accurate diagnosis for their second visit and thus, the cost saving nationwide is the minimum value. We then compared the saving of bringing videos with that of only description available to study the value of videos. The formulas are as follows.

A. The cost saving when choosing online consultation on their first visit

\[
P_{c} \sum_{n=1}^{N_1} \cdot p \cdot (\Delta S_{ep} + \Delta S_{non-ep} \cdot R_{non-ep})
\]

B. The additional cost of traditional outpatient consultation compared with online consultation when videos are not available

\[
S_1 = \sum_{n=1}^{6} (\Delta S_{ep1} \cdot P_{d-ep} + \Delta S_{non-ep1} \cdot R_{non-ep} \cdot P_{d-nep} + \Delta S_{ep2} \cdot (1-P_{d-ep}) + \Delta S_{non-ep2} \cdot R_{non-ep} \cdot (1-P_{d-nep}))
\]

C. The additional cost of traditional outpatient consultation compared with online consultation when videos are available

\[
S_2 = \sum_{n=1}^{6} (\Delta S_{ep1} \cdot P_{v-ep} + \Delta S_{non-ep1} \cdot R_{non-ep} \cdot P_{v-nep} + \Delta S_{ep2} \cdot (1-P_{v-ep}) + \Delta S_{non-ep2} \cdot R_{non-ep} \cdot (1-P_{v-nep}))
\]

D. The benefit of bringing videos and choosing online consultation for the correct diagnosis of infants with paroxysmal events

\[
\frac{S_1 - S_2}{S_1} \times 100\%
\]

In the 4 formulas, n represents different area (n1, Northern China, n2, Northwest China, n3, Southwest China, n4, Central China, n5, Eastern China, n6, Northeast China). Variable p represents the incidence of epilepsy in the region and N represents the total population in the region. P_c represents the proportion of children patients. \(\Delta S_{ep}\) represents the saving cost for epilepsy patients on online consultation, and \(\Delta S_{non-ep}\) represents the saving cost for non-epilepsy patients on online consultation. \(R_{non-ep}\) represents the proportion of non-epileptic seizures versus epileptic seizures in the paroxysmal events. \(N_i\) presents the epilepsy infant population nationwide. \(\Delta S_{ep1}\)
represents the charge for epileptic patients on their first visit. \( \Delta S_{\text{ep}2} \) represents the charge for epileptic patients on their second visit. \( \Delta S_{\text{non-ep}1} \) represents the charge for non-epileptic patients on their first visit. \( \Delta S_{\text{non-ep}2} \) represents the charge for non-epileptic patients on their second visit. \( P_{d-\text{ep}} \) represents the percent of correct diagnosis for epileptic patients without videos of paroxysmal events on their first visit. \( P_{d-\text{nep}} \) represents the percent of correct diagnosis for non-epileptic patients without videos of paroxysmal events on their first visit. \( P_{v-\text{ep}} \) represents the percent of correct diagnosis for epileptic patients with videos of paroxysmal events on their first visit. \( P_{v-\text{nep}} \) represents the percent of correct diagnosis for non-epileptic patients with videos of paroxysmal events on their first visit.

**Results**

1. **Mobile phone videos in increasing the diagnosis accuracy**

A total of 452 questionnaires were collected in this study, 301 of which met the criteria (66.6%) and were included in the study. Table 1 shows the descriptive data of the participants. The mean number of videos correctly identified through episode description and through video and episode descriptions was 7.5 of 12 and 8.4 of 12, respectively. Through episode description, the percentage of correctly identified epileptic and non- epileptic events ranged from 77.1% to 91.0% and 27.6% to 67.8%, respectively; through video and episode descriptions, the percentage of correctly identified epileptic and non-epileptic events ranged from 86.7% to 96.7% and 28.6% to 76.4%, respectively. Details of the 12 video recordings of infants with seizure and
non-seizure movements are summarized in Table 2.

For epileptic events, the mean correct identification rate of description was 84.9%, and that of videos and description was 88.8%. The addition of videos increased the mean correct identification rate by 3.9%, and the correct identification rates of the two methods were significantly different. For non-epileptic events, the mean correct identification rate of description was 39.9%, and that of videos and description was 51.4%. The addition of videos increased the mean correct identification rate by 11.5%, and the correct identification rates of the two methods were also significantly different.

On the analyses of doctor’s background information, we found the working years was the key factor to correct diagnosis. As a whole, whether or not videos were provided, the level of the doctor's hospital and education background were irrelevant to the correctness of the diagnosis, and the diagnosis from neurologic pediatrician with relatively longer working years was more accurate. When only parent's description was available, for epileptic seizures, profession (neurologic pediatrician or not) was the only factor that can affect the correctness of the diagnosis; for non-epileptic seizures, neurologic pediatrician with relatively longer working years could make a more accurate diagnosis. When both description and video were available, for epileptic seizures, profession (neurologic pediatrician or not) and hospital level were the two factors that can affect the correctness of the diagnosis; for non-epileptic seizures, working years and profession were related to the correctness of the diagnosis. The statistical results are shown in table 3.
2. Saving cost on infant paroxysmal events for online consultation

The mean of transportation fee, accommodation fee, further examination fee, and loss of wages according to the published literature (24-29) and governmental report (http://www.gzjyj.gov.cn/zwgk/zcfg/92298.shtml) is 290.0 dollars (1856 yuan), 86.3 dollars (552 yuan), 192.9 dollars (1228 yuan), and 104.7 dollars (670 yuan), respectively. The annual new children patients (under 9 years old) population is 197945 in China. Online consultation can save $1.28 \times 10^8$ dollars ($8.22 \times 10^8$ yuan) per year. For infants with paroxysmal event videos on their first visit, at least 12.02% of the total cost for correct diagnosis can be saved.

Discussion

Our study investigated the value of bringing videos on the diagnosis of paroxysmal events in infancy. We excluded the recorded videos with poor quality, but in real clinical work, videos from patients' caretakers may not be sound enough and it will also influence the diagnosis (33). Therefore, while emphasizing the importance of recording video, the quality of videos should also be emphasized. In some ways, doctors can teach patients' family members how to record high quality videos.

It is very meaningful for the first visit patients to carry videos of the paroxysmal events, whether they will be diagnosed as epilepsy or not. Videos contribute a higher value than the oral description from parents to the accurate diagnosis. In our study, for epileptic events, the addition of videos increased the mean correct identification rate by 3.9%, and for non-epileptic events, the addition of videos increased the mean
correct identification rate by 11.5%. Besides, compared with descriptions, videos are better at restoring all the information of paroxysmal events. In a previous study including 45 semiological signs that can be used to distinguish PNES and ES, only 6 were proved reliable and eyewitness reports of these signs were proved to be unreliable (9). Due to lack of relevant knowledge, parents' description may exaggerate some clinical symptoms, and it will influence doctors’ judgments. The videos recorded by the parents can completely avoid the occurrence of the situation above if the whole process can be fully reflected. So, if doctors can only rely on history-taking for their diagnosis at patients’ first visit, the difficulty in diagnosis will be huge and there will inevitably be more cost on examination and even medication. Besides, if there are videos available, some of these patients will be diagnosed as non-epileptic just by the video recording and there will no need for them to perform more relevant examinations. Although some will be diagnosed as epileptic, the videos can also save their cost on examination because the video can aid interpretation of ambulatory EEG in approximately one third of patients and they may no longer need to perform video EEG(21). Thus, videos can help doctors make correct diagnosis easier and earlier(34) and the benefit of early diagnosis can sometimes be huge because it may improve the prognosis of epileptic infants, especially those with infantile spasms(35, 36).

For a paroxysmal event, doctor may be able to easily identify it as a non-epileptic through video and another 11.5% of the non-epileptic patients will then bear a lighter mental and financial burden from subsequent diagnosis and treatment.

Experienced doctors, especially experienced neurologists, rather than doctors in
higher-level hospitals or with better educated background, are better candidates for patients on their first visit. After the onset, the caretakers naturally think that the better educated and experienced neurologists in the higher-level hospital are their first choice. However, the level of a hospital and doctor's education background are not significant according to our study. Experienced doctors can obtain higher diagnostic accuracy rate, and the neurologists have their advantage on differentiating epileptic seizure. Nagy et al. (37) have reported that the correct rate of first-year medical students was even lower than that of patients’ parents. The process of diagnosis of epilepsy is a sophisticated process and therefore, patients should choose the experienced doctor, especially experienced neurologists for diagnosis and treatment, regardless of their hospital level or education background.

Online consultation is a better choice for infants with paroxysmal events at their first visit. Previous studies have shown that the incidence of epileptic misdiagnosis in online diagnosis and treatment mode is of no difference from that of the traditional clinic outpatient mode (38). Moreover, online diagnosis and treatment has a huge advantage in integrating medical resources, reducing patients' costs and improving patients' self-management level (39-42). Many medical applications for smart phones have been developed and widely used by health professionals and patients. In 2016, the Chinese mHealth market was valued at 7 billion RMB and exceeded over 10 billion RMB in 2017 (data source: center for technology innovation at the Brookings Institution). It is expected to soon play an important role in the Chinese healthcare market, although the mobile healthcare applications market is still nascent. Besides,
for patients during their first visit, there has been no examination results available, especially simultaneous EEG monitoring. So, the diagnosis accuracy cannot be sound enough. Like what has been revealed in our study, even with video recording, the accuracy rate for non-epileptic event was only 51.4%. So, they may cost a lot on transportation, accommodation, lost wages, and registration only to find doctors need more examination results before making final diagnosis and they have to go back home or live nearby the hospital for several days before their appointment date for the further examinations. But many costs would have been saved if they had turned to online consultation. According to our study, the annual new children patients (under 9 years old) population is 197945 in China. Online consultation can save $1.28 \times 10^8$ dollars ($8.22 \times 10^8$ yuan) per year for these patients. For infant with paroxysmal event videos, at least 12.02% of the total cost for correct diagnosis can be saved. So, we recommend all the infant patients with paroxysmal events choose online consultation for their first visit. This means more to non-epileptic patients, because this not only reduces their economic burden, but also allows them not to bear the burden of epilepsy, which, actually, is irrelevant to them.

In the present study, we included a special non-epileptic event, Sandifer syndrome, which is a type of gastroesophageal reflux(43). Gastroesophageal reflux associated with laryngospasm in infants may cause events that can be misdiagnosed as seizures because of the presence of limb posturing, eye deviation, and even opisthotonus(44). These events occur in sleep and thus cause diagnostic difficulties(15). In our study, instead of increasing the identification rates, the videos did not help clinicians to make
differential diagnosis. Thus, video-EEG was still necessary to confirm the diagnosis.

One of the limitations of this study is the use of non-random samples of videos. From the 71 videos recorded by parents, only those showing clarity and suitability were selected. Thus, the sample size was small and not representative enough for all types of seizures.

**Conclusion**

Mobile phone videos can increase the diagnostic accuracy of clinicians. Online consultation can serve as a portable platform for patients with paroxysmal events. When choosing online consultation, doctors with more experience, especially the pediatric neurologists, rather than the one with shorter working years but with better education background and working in higher level hospital should be their first choice.

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