

Clinical Application and Research of Telemetry Electrocardiographic Monitoring in Pediatric Patients

Qiuling Yi

Xichang People's Hospital, Xichang 615000, Sichuan, China

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Abstract: Pediatric patients have a wide age range, weak independent cooperation ability, rapid disease changes, and obvious individual differences in physiological indicators. Traditional bedside electrocardiographic monitoring has problems such as multiple wires, limited mobility, easy data interference, and poor patient compliance. Telemetry electrocardiographic monitors, with characteristics such as wireless transmission, continuous monitoring, real-time early warning, and portability, have been increasingly widely used in pediatric clinical practice.

Keywords: Telemetry electrocardiographic monitoring; Pediatric patients; Wireless monitoring; Intensive care; Clinical nursing; Arrhythmia

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1. Introduction

Telemetry electrocardiographic monitoring has emerged as a valuable tool in pediatric clinical practice, addressing the limitations of traditional bedside monitoring, such as restricted mobility, wire-related discomfort, and poor patient compliance. By enabling wireless, continuous, and real-time transmission of cardiac signals, telemetry systems are particularly suitable for children, who often have wide age ranges, rapid disease progression, and limited cooperation. This paper reviews the technical characteristics, clinical applications, nursing strategies, and existing challenges of telemetry electrocardiographic monitoring in pediatric patients, highlighting its role in improving diagnostic accuracy, patient safety, and overall quality of care.

2. Overview of telemetry electrocardiographic monitors

2.1. Basic structure and working principle

The telemetry electrocardiographic monitoring system is mainly composed of four parts: a portable electrocardiographic acquisition terminal, a wireless transmission module, a central monitoring workstation,

and a data storage and alarm device. Electrode patches collect weak electrocardiographic signals from the human body surface. After amplification, filtering, noise reduction, and analog-to-digital conversion, the data is transmitted in real-time to the nurse's station or doctor's terminal via Bluetooth, Wi-Fi, or mobile networks. The system can automatically analyze indicators such as heart rate, rhythm, ST segment, QT interval, and respiratory rate. When the data exceeds the preset range, it immediately activates an audio-visual alarm to remind medical staff to handle it in a timely manner. Compared with traditional monitoring, the telemetry mode breaks free from cable constraints and can achieve continuous monitoring in a mobile state within a certain range, making it more suitable for the special group of children.

2.2. Technical characteristics

First, wireless and portable, reducing constraints. Children can move freely, eat, play, and undergo examinations in the ward, significantly improving comfort and cooperation, and reducing monitoring interruptions caused by crying and restlessness. Second, long-term continuous monitoring. It can achieve uninterrupted recording for hours to days, improving the detection rate of transient and paroxysmal electrocardiographic abnormalities, and making up for the shortcomings of conventional electrocardiograms with short time and limited information. Third, real-time early warning and rapid response. The central monitoring platform can monitor multiple beds simultaneously, with immediate prompts for abnormal situations, shortening the rescue response time and improving the level of medical safety. Fourth, traceable data for easy evaluation. The system automatically stores waveforms and trend graphs, supporting playback, comparison, and export, providing an objective basis for curative effect judgment, disease analysis, teaching, and scientific research. Fifth, expandable multi-parameter monitoring. High-end equipment can synchronously integrate monitoring of blood oxygen, respiration, body temperature, body position, etc., to meet the comprehensive monitoring needs of critically ill children ^[1].

2.3. Principles for selecting pediatric equipment

For neonates and infants, priority is given to small, lightweight acquisition equipment with hypoallergenic electrodes and firm fixation to reduce skin irritation and compression. For preschool and school-age children, models that are easy to wear, anti-interference, and have gentle alarm sounds are selected to reduce fear. For critically ill and post-operative children, models with stable transmission, strong battery life, and support for synchronous multi-parameter monitoring are used to ensure continuous and reliable monitoring.

3. Main clinical applications of telemetry electrocardiographic monitoring in pediatrics

3.1. Perioperative monitoring of congenital heart disease

Children with congenital heart disease have significant differences in preoperative cardiac function and are prone to complications such as arrhythmia, pericardial effusion, and low cardiac output syndrome after surgery. Telemetry electrocardiographic monitoring can continuously observe changes in heart rate, rhythm, and ST segment, early identify dangerous signals such as supraventricular tachycardia, ventricular premature beats, and atrioventricular block, providing a basis for adjusting medication, volume management, and early intervention, reducing the incidence of postoperative malignant cardiac events and promoting recovery. For children after complex congenital heart disease surgery, long-term and continuous electrocardiographic

monitoring is particularly important, which can promptly detect early signs of hemodynamic instability and improve the success rate of treatment ^[2].

3.2. Screening and definite diagnosis of arrhythmia

Common pediatric arrhythmias include supraventricular tachycardia, premature beats, atrioventricular block, long QT syndrome, and Wolff-Parkinson-White syndrome. Most of them occur paroxysmally, and conventional electrocardiograms are prone to missed diagnosis. Telemetry monitoring can capture abnormal electrocardiographic events over a long period, recording the onset, termination, frequency, duration, and inducing factors, providing objective evidence for drug treatment, radiofrequency ablation surgery, and pacemaker implantation. For children with unexplained syncope, palpitations, and chest tightness, telemetry electrocardiographic monitoring can significantly improve the detection rate of the cause and provide key support for clinical diagnosis.

3.3. Continuous monitoring of critically ill children

Children with neonatal asphyxia, premature infants, severe pneumonia, septic shock, respiratory failure, etc., are often accompanied by myocardial injury, heart rate fluctuations, apnea, and other problems. Telemetry monitoring can maintain uninterrupted monitoring during transportation, examinations, and nursing operations, promptly detect the trend of disease deterioration, and improve the success rate of critical care. In the neonatal intensive care unit, telemetry monitoring can reduce the constraints of wires on children, facilitate skin care and position changes, and at the same time achieve continuous electrocardiographic and respiratory monitoring, early identifying apnea and heart rate abnormalities, and reducing the incidence of adverse events in critically ill children ^[3].

3.4. Whole-process monitoring of children with myocarditis and cardiomyopathy

Children with viral myocarditis are prone to severe arrhythmia and decreased cardiac function in the acute phase; children with hypertrophic cardiomyopathy, dilated cardiomyopathy, etc., require long-term monitoring of QTc interval, ST-T changes, and rhythm stability. Telemetry monitoring can dynamically reflect the degree of myocardial injury and changes in the condition, early warn of high-risk events, and ensure the safety of treatment. For children in the recovery phase of myocarditis, outpatient telemetry monitoring can help doctors evaluate the myocardial repair situation, guide the adjustment of activity levels and medication, and achieve whole-process management from the acute phase to the recovery phase ^[4].

3.5. Postoperative rehabilitation monitoring in surgery

After pediatric cardiothoracic, abdominal, and orthopedic surgeries, anesthetic drug metabolism, pain stimulation, and stress responses can all lead to increased heart rate, arrhythmia, or hypoxemia. Telemetry monitoring supports early ambulation of children, accelerates the rehabilitation process under the premise of ensuring safety, and reduces bedridden complications such as pulmonary infection and venous thrombosis. Compared with traditional monitoring, the telemetry mode is more conducive to the implementation of the enhanced recovery after surgery (ERAS) concept, improving children's mobility and shortening the length of hospital stay.

3.6. Monitoring of drug cardiotoxicity

Some clinical drugs such as digitalis, antiarrhythmic drugs, and certain chemotherapeutic drugs have potential cardiotoxicity, and close monitoring of heart rate and QT interval changes is required during use. Telemetry electrocardiographic monitoring can reflect drug effects and adverse reactions in real-time, helping doctors adjust doses in a timely manner and avoid drug-related cardiac damage. For children who have long-term use of drugs that affect cardiac conduction, continuous electrocardiographic monitoring can reduce the risk of malignant arrhythmia and improve medication safety ^[5].

3.7. Post-discharge home telemonitoring

Children with complex congenital heart disease, post-arrhythmia surgery, pacemaker implantation, etc., still face the risk of condition fluctuations after discharge. Home telemetry equipment can upload monitoring data to the hospital platform, realizing continuous post-discharge management, reducing unnecessary re-consultations, early detecting abnormalities and intervening in a timely manner, and reducing the readmission rate. Home telemetry monitoring not only improves the quality of life of children but also reduces the pressure and economic burden of family care, and is an important supplement to the pediatric chronic disease management model.

4. Clinical advantages of telemetry electrocardiographic monitoring in pediatrics

4.1. Significantly improve patient compliance

The wireless design reduces entanglement, compression, and discomfort, lowers the incidence of crying and restlessness, and is particularly suitable for infants and active children. Children can move and play normally under monitoring, with less psychological pressure and higher cooperation, which is conducive to improving the accuracy and continuity of monitoring data ^[6].

4.2. Improve the detection rate of electrocardiographic abnormalities

Long-term continuous monitoring can greatly improve the detection probability of paroxysmal and asymptomatic arrhythmias, which has obvious advantages over conventional electrocardiograms. A large number of clinical studies have shown that the detection rate of transient arrhythmia, myocardial ischemia, and other events by telemetry electrocardiographic monitoring is significantly higher than that of conventional electrocardiographic examinations, which can effectively reduce missed diagnoses and misdiagnoses.

4.3. Strengthen safety early warning capabilities

Centralized central monitoring and real-time alarm for abnormalities help medical staff quickly identify dangerous situations, improving the success rate of rescue and the level of medical safety. In multi-bed wards, the telemetry system can achieve centralized management and unified early warning, optimize the allocation of human resources, and improve the efficiency of emergency response.

4.4. Optimize nursing work efficiency

It reduces repetitive work such as wire arrangement and electrode re-fixation, lowers the pressure of nurses' bedside rounds, and improves the overall quality of nursing. Nurses can observe the electrocardiographic conditions of multiple children in real-time through the central station, and spend more time on condition observation, basic nursing, and health guidance, improving the level of nursing services.

4.5. Support individualized precision medicine

Monitoring data can form trend curves and complete waveform records, facilitate the evaluation of disease changes, treatment effects, and prognosis, and providing support for individualized plans. Doctors can adjust medications and formulate rehabilitation plans according to continuous monitoring results, realizing the transformation from empirical treatment to precision treatment ^[7].

4.6. Adapt to children's physiological characteristics

The equipment can set different alarm thresholds according to age, weight, and condition, which is more in line with the physiological differences of neonates, infants, children, and adolescents. Compared with the unified standards for adults, the individualized alarm settings for pediatrics can reduce false alarms and missed alarms, and improve the effectiveness of monitoring.

5. Operational points and nursing strategies of telemetry electrocardiographic monitoring in pediatrics

5.1. Skin care and electrode placement

Clean the skin before placing electrodes to remove sweat, oil, and fine hair to ensure signal quality. For neonates and children with sensitive constitutions, use hypoallergenic electrodes and regularly change positions to prevent redness, damage, and dermatitis. For restless children, breathable films or special fixing vests can be used to strengthen fixation and reduce electrode detachment. Nursing staff should be proficient in the electrode placement positions for children of different ages to ensure clear waveforms and minimal interference ^[8].

5.2. Individualized alarm settings

Set reasonable upper and lower limits according to age, disease type, and basic heart rate to avoid false alarms or missed alarms caused by unified standards and reduce alarm fatigue. The normal values of heart rate vary greatly among neonates, infants, and school-age children, so hierarchical settings must be carried out. At the same time, the alarm sensitivity can be adjusted according to the severity of the condition to reduce invalid alarms under the premise of ensuring safety.

5.3. Reduce signal interference

Keep away from electromagnetic equipment such as mobile phones, microwave ovens, and monitors; mark children during severe crying and activities to facilitate waveform interpretation. Nursing staff should master common interference sources and elimination methods to ensure stable and reliable electrocardiographic signals. For transient waveform interference during movement, it should be identified and recorded in a timely manner to avoid misjudgment as abnormal rhythm.

5.4. Health education for family members

Explain the purpose, precautions, and emergency handling methods of monitoring to parents, alleviate anxiety, and improve cooperation and care capabilities. Guide parents to correctly protect the acquisition equipment to avoid collision, water ingress, and excessive pulling. Through health education, family members can actively participate in the monitoring process and jointly ensure the safety of children.

6. Existing problems and improvement measures

6.1. Existing problems

First, the skin of young children is delicate, and long-term wearing of electrodes is prone to local irritation, redness, and even damage. Second, children's hyperactivity and crying are likely to cause electrode loosening and signal interruption, affecting the continuity of monitoring. Third, unreasonable alarm parameter settings led to a high false alarm rate, which is likely to cause alarm fatigue among medical staff. Fourth, some equipment lacks special algorithms for children, with limited waveform recognition accuracy and weak ability to judge complex arrhythmias. Fifth, there is a lack of unified standards for the transmission, interpretation, and management of home monitoring data, and the connection between in-hospital and out-of-hospital data is not smooth. Sixth, the procurement and maintenance costs of equipment are relatively high, which to a certain extent limits the popularization and application in primary hospitals^[9].

6.2. Improvement countermeasures

Promote hypoallergenic flexible electrodes and hydrocolloid dressings to reduce skin irritation and damage and improve wearing comfort. Optimize the fixing method, adopt an integrated wearing design, elastic straps, or special vests to improve equipment stability. Establish an age-stratified alarm system for pediatrics, refine parameters combined with disease types and conditions, and reduce invalid alarms. Introduce AI intelligent analysis algorithms to improve the accuracy of automatic arrhythmia recognition and reduce the burden of manual interpretation. Formulate operating specifications for pediatric telemetry monitoring and home monitoring processes, unify data standards, and realize seamless connection between in-hospital treatment and home management. Strengthen equipment maintenance and personnel training, extend service life, improve use efficiency, gradually reduce application costs, and promote the popularization of technology in primary hospitals^[10].

7. Development trends

First, wearable and non-invasive monitoring. In the future, telemetry monitoring equipment will develop in the direction of being smaller, lighter, and softer, adopting flexible sensors and non-invasive attachment technology to achieve almost non-invasive long-term monitoring. Second, artificial intelligence-assisted diagnosis. AI automatically identifies arrhythmia, myocardial ischemia, and risk early warning, improving diagnostic efficiency and accuracy, and reducing the workload of medical staff. Third, integration of 5G telemedicine. It supports cross-regional real-time monitoring, remote consultation, and home follow-up, expanding the coverage of high-quality medical services, especially benefiting children in remote areas. Fourth, multi-parameter integrated monitoring. Integrated analysis of electrocardiography, respiration, blood oxygen, blood pressure, body temperature, and other data to achieve comprehensive evaluation and early warning. Fifth, full-cycle health management. Extend from in-hospital monitoring to long-term post-discharge management, building an integrated child's cardiac health protection model of screening–diagnosis–treatment–rehabilitation–follow-up.

8. Conclusion

With the core advantages of being wireless, continuous, real-time, and mobile, telemetry electrocardiographic

monitors are highly consistent with the clinical characteristics of pediatric patients, such as a wide age range, low cooperation, and rapid disease changes. They have important application value in congenital heart disease, arrhythmia, intensive care, postoperative rehabilitation, drug monitoring, and home follow-up. It can not only improve the detection rate of electrocardiographic abnormalities, reduce the risk of adverse events, and enhance medical safety but also improve children's comfort and nursing efficiency, which has significant clinical significance. At present, pediatric telemetry monitoring still faces problems such as skin tolerance, signal interference, false alarms, and algorithm adaptation, which require continuous improvement in equipment research and development, process standardization, nursing optimization, and intelligent technology application. With the continuous development of wearable devices, artificial intelligence, and telemedicine, telemetry electrocardiographic monitoring will become more accurate, intelligent, and convenient, serving as an indispensable important tool in pediatric cardiovascular safety management and providing more reliable protection for children's health.

Disclosure statement

The author declares no conflict of interest.

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