Invasive and Non-invasive Blood Pressure Analysis in an Electrical Injury Amputee: A Case Report and Literature Review (Post-print)

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Abstract

Electric shock injury is a common form of trauma. Characterized by high-voltage current passing through the body, it typically involves one entry point and multiple exit points, and is prone to causing destructive injuries, severe post-traumatic stress responses, and secondary infections, with rapid clinical deterioration. Blood pressure monitoring serves as a commonly used method for accurate and timely assessment of patient condition. This article analyzes and compares invasive blood pressure (IBP) and non-invasive blood pressure (NBP) monitoring results in a patient with double upper limb and right lower limb amputation following high-voltage electric shock injury, and through literature review, summarizes and discusses the differences between IBP and NBP monitoring to provide reference for effective clinical blood pressure monitoring in severe trauma patients.

Full Text

Preamble

Title

Analysis and Literature Review of Invasive and Noninvasive Blood Pressure in a Case of Electrical Injury Leading to Amputation

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Abstract

Electrical injury is one of the common traumatic injuries. When high-voltage current passes through the body, there is usually one entrance and multiple exit wounds, which can easily lead to destructive tissue damage, severe post-traumatic stress response, and secondary infection, with rapid changes in clinical condition. Blood pressure monitoring is a common method for accurate and timely assessment of patient status. This article analyzed and compared invasive blood pressure (IBP) and noninvasive blood pressure (NBP) monitoring results in a patient with bilateral upper limb and right lower limb amputation following high-voltage electrical injury. Through literature review, we summarized and discussed the differences between IBP and NBP monitoring to provide references for clinically effective blood pressure monitoring in patients with severe trauma.

Keywords: electrical injury; invasive blood pressure; noninvasive blood pressure; literature review

Introduction

High-voltage electrical injury (current > V) is a common trauma in burn surgery, with the highest incidence of limb trauma. It is characterized by severe tissue destruction at the entrance and exit wounds; deep burns of degree or higher; arterial hemorrhage and cardiac arrest due to vascular wall damage from current passing through blood vessels; and acute kidney injury caused by myoglobin from destroyed muscle cells blocking renal tubules. Patients with this condition experience rapid changes in clinical status and require high standards for blood pressure monitoring due to the need for blood volume assessment during shock and vascular wall damage.

Our department successfully treated a patient with degree high-voltage electrical injury on date, involving severe destruction of both upper limbs and the right lower limb, secondary arterial damage with massive hemorrhage, and subsequent amputation of the right lower limb and both upper limbs. The patient's limb trauma created extreme difficulties for blood pressure monitoring. Both noninvasive blood pressure (NBP) and invasive blood pressure (IBP) measurement methods were employed sequentially. This article analyzes the IBP and NBP monitoring results during the patient's treatment and discusses the differences in combination with literature review.

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Case Report

The patient was a male, admitted days after V high-voltage electrical injury. Admission assessment revealed severe tissue destruction, necrosis, and blackening of both upper limbs and the right lower limb, with scattered deep burns on the buttocks, back, and left lower limb, covering approximately %TBSA (total body surface area).

After admission, due to complications of acute pulmonary edema, severe hypoxemia, acute renal insufficiency, and anuria, emergency treatment was provided including tracheostomy with ventilator assistance, bedside continuous renal replacement therapy (CRRT), and bedside cardiac monitoring of NBP in the right upper limb, respiratory rate, heart rate, and pulse oxygen saturation. On day after admission, emergency amputation of the right lower leg and left forearm was performed, with debridement and limb salvage treatment of the right upper limb. A left dorsalis pedis artery catheter was placed for IBP monitoring. Post-catheterization, IBP continuously fluctuated mmHg/mmHg. Despite treatment with intravenous sodium nitroprusside and oral nifedipine sustained-release tablets as prescribed, the antihypertensive effect was not significant. Therefore, simultaneous NBP monitoring of the right upper limb was performed in combination with IBP monitoring to provide reference for physicians in using antihypertensive drugs and observing the condition.

days later, due to severe tissue destruction of the right forearm, dressing changes after debridement affected NBP monitoring, which was forced to terminate. Only IBP monitoring via the remaining left lower limb dorsalis pedis artery could be used. On day after admission, sudden rupture of the right forearm radial artery with massive hemorrhage occurred, which was life-threatening, and emergency right forearm amputation was performed. After treatment, the patient's condition stabilized, vital signs became stable, and wounds healed well. The patient was discharged days after hospitalization.

During months of telephone follow-up, home NBP monitoring results were obtained, guidance on wound protection and rehabilitation exercises was provided, and information about activities and self-care methods after prosthesis installation was understood and guided.

Follow-up results at years: After amputation, wounds healed well. NBP monitoring results obtained via electronic sphygmomanometer in the right upper limb fluctuated mmHg. Both hands and right lower limb were fitted with prostheses months after discharge, with good adaptation. With family assistance, the patient could achieve self-care and return to work.

Methods

Blood Pressure Monitoring Challenges

The common site for NBP measurement is the mid-upper arm. When upper limb blood pressure cannot be monitored, the latest expert consensus indicates that ankle measurement of lower limb blood pressure can be selected. In this case, both forearms suffered destructive damage from high-voltage electrical injury. On day after admission, the left upper limb was amputated below the elbow joint, the right lower limb was amputated cm below the knee, and the right upper limb destruction was concentrated in the forearm and hand area, injuring the radial artery. The left lower limb trauma was concentrated in the lower leg, with deep burns at the ankle and obvious post-injury swelling. Under these circumstances, the right upper limb and left lower limb were temporarily treated with limb salvage.

NBP Measurement Method

The measurement site was selected as the right upper limb brachial artery, ensuring the cuff was at the same level as the invasive pressure sensor to prevent static pressure differences. During measurement, the lower edge of the cuff was placed cm above the elbow fossa, with the bladder width covering % of the upper arm length and the length reaching % of the upper arm circumference.

IBP Measurement Method

The puncture point was located at the left dorsalis pedis artery. Regular heparin mmHg was placed in a pressurized infusion bag, using manual balloon inflation to maintain pressure values at mmHg. The pressure sensor was fixed at a height consistent with the fourth intercostal space at the mid-axillary line, level with the right atrium and close to the aortic root. When the patient's position changed, the sensor height needed to be adjusted at any time to avoid measurement errors. Arterial pressure zeroing method: The zero line must be completely filled with fluid. During zeroing, personnel should not touch the bed to avoid human interference with the instrument. The pressure sensor stopcock was turned to the air end while activating the zeroing function on the monitor. Zeroing was successful when tracing the zero line at mmHg pressure. Subsequently, the pressure sensor stopcock was closed to the atmosphere, and no further zeroing was required during the measurement period.

During the two groups of blood pressure monitoring, the patient did not receive vasoactive drugs.

Other Data Monitoring

PHILIPS G cardiac monitor was used to monitor pulse oxygen and heart rate every hour; mercury thermometer was used to measure body temperature, with ice pack physical cooling given at ℃. h/次.

Statistical Analysis

SPSS software was used. Measurement data were expressed as mean ± standard deviation (x ± s). Repeated measurement data in chronological order of trauma were analyzed using repeated measures methods. Overall measurement data comparison between IBP and NBP used paired sample t-test, with P < indicating statistically significant difference. IBP was measured for d, while NBP was monitored for d. The obtained results are shown in Table. Paired t-test of IBP and NBP.

Discussion

This patient had no previous medical history or hypertension history. After high-voltage electrical injury, the condition was severe. IBP monitoring was performed at the lower limb dorsalis pedis artery, which is not a common clinical measurement site. Analysis of the difference between IBP and NBP may be related to the patient's disease status and blood pressure measurement site. Therefore, we reviewed the differences between IBP and NBP in different populations and measurement methods to help analyze possible reasons for the differences observed in this patient.

Analysis of Differences Between IBP and NBP in High-Voltage Electrical Injury Patients

In this case of high-voltage electrical injury after amputation, paired blood pressure data sets between invasive dorsalis pedis artery and contralateral noninvasive brachial artery showed obvious positive correlation between IBP and NBP. Comparison between invasive systolic pressure and noninvasive systolic pressure showed statistically significant differences [mmHg vs. ( ) mmHg, t=]; comparison between invasive diastolic pressure and noninvasive diastolic pressure also showed statistically significant differences [( ) mmHg vs. ( ) mmHg, t=]. The data demonstrated obvious differences between the two measurement methods, with the difference in systolic pressure being significantly greater than that in diastolic pressure. The average difference between invasive and noninvasive systolic pressure was mmHg.

Fan et al. and Cheng et al., Han et al., and Zhou et al. conducted comparisons of IBP and NBP in critically ill patients, all pointing out that differences exist between IBP and NBP in severe patients, and the magnitude of deviation is significantly correlated with blood pressure levels. Based on NBP and IBP measurement data from MIMIC- patients, Fan et al. concluded that the difference between IBP and NBP was. Zhang et al. conducted correlation analysis of IBP and NBP monitoring values in cases, concluding that both invasive systolic and diastolic pressures were higher than NBP systolic and diastolic pressures. When patient blood pressure values exceed a certain critical value, IBP is greater than NBP, with the difference between systolic pressures being more obvious. Therefore, in critically ill patients, when blood pressure values are high, IBP is greater than NBP.

Through Meta-analysis of hypertensive and shock patients, Wang et al. similarly concluded that in shock hypotensive patients, noninvasive systolic pressure measurements were higher than invasive measurements, while in hypertensive patients, noninvasive systolic pressure was lower than invasive measurements. For hypertensive patients, invasive systolic pressure was significantly higher than noninvasive, and the higher the blood pressure, the greater the difference between the two, while there was no statistical significance in diastolic pressure results. Considering that the large difference between invasive and noninvasive systolic pressure in critically ill patients may be related to disease course changes, Jia et al. proposed in their literature that when patients have adequate blood perfusion, the kinetic energy of cardiac pulsation is directly conducted through blood flow facing the arterial catheter opening and converted into pressure, which is higher than the lateral pressure of blood on vessel walls (cuff pressure measurement value). This viewpoint explains the hypervolemic state after post-traumatic stress response in critically ill patients and in this case of high-voltage electrical injury.

Interestingly, Gao et al., in elective neurosurgery patients under general anesthesia, obtained dorsalis pedis IBP significantly lower than posterior tibial artery NBP at the ankle after eliminating patient mental tension, and similarly pointed out the blood pressure reversal pattern: when systolic pressure mmHg, the average deviation between invasive and noninvasive diastolic pressure was (- mmHg); when systolic pressure mmHg, the average deviation between invasive and noninvasive systolic pressure was (- mmHg). Analysis of the result that IBP was lower than NBP in their article may be related to the stable condition of elective surgery patients and the fact that blood pressure measurement sites were both in the lower limbs. So, what differences would exist in blood pressure acquisition, especially between IBP and NBP at different sites? This warrants further exploration.

Jia et al., using patients undergoing lower limb fracture and lower abdominal surgery in supine position, similarly pointed out this reversal (inversion) pattern between IBP and NBP, specifically indicating the critical value range, with the reversal critical value being (mmHg. The difference range between invasive and noninvasive systolic pressure was - mmHg, while the difference range between invasive and noninvasive diastolic pressure was always negative, which differs from our results where the difference range between invasive and noninvasive diastolic pressure was always positive. The diastolic pressure difference was the same as in Zhang et al.'s case results.

Different Measurement Sites

In the literature, common measurement sites for IBP and NBP are upper limb brachial artery NBP and radial artery IBP. Han et al., Jia et al., Cheng et al., and Zhang et al. all collected data on radial artery IBP and upper limb brachial artery NBP, with hypertensive patients showing higher invasive systolic pressure than noninvasive systolic pressure, though with certain differences in values. Han et al. obtained IBP and NBP data from the same side of the upper arm brachial artery in critically ill patients, with results indicating invasive systolic pressure greater than noninvasive systolic pressure and invasive diastolic pressure less than noninvasive diastolic pressure, suggesting this may be related to sample size and vasoactive drug use in the hypotensive group, without indicating a reversal phenomenon in blood pressure changes. Cheng et al. similarly compared radial artery IBP and ipsilateral brachial artery NBP in severe patients, finding that in non-shock patients without vasoactive drugs, the measurement deviation between invasive and noninvasive systolic pressure was significantly higher than in shock patients with vasoactive drugs, with the maximum deviation between invasive and noninvasive systolic pressure reaching mmHg, invasive systolic pressure mmHg, and deviation between invasive and noninvasive systolic pressure mmHg, results somewhat similar to our case. Han et al. and Cheng et al. had the same measurement sites but quite different results. Analysis of the two articles shows differences not only in the diseases themselves but also in whether vasoactive drugs were used. Obviously, measurement site is not the only influencing factor between IBP and NBP.

Even in the upper limbs, such significant differences exist between invasive and noninvasive systolic pressure. Regarding blood pressure differences between lower limb invasive and upper limb noninvasive measurements, Zhou et al. collected paired IBP and NBP data from postoperative neurosurgery intensive care patients. Among them, comparison between dorsalis pedis invasive systolic pressure and brachial artery noninvasive systolic pressure [mmHg vs. ( ) mmHg, t=]; comparison between dorsalis pedis invasive diastolic pressure and brachial artery noninvasive diastolic pressure [( ) mmHg vs. ( ) mmHg, t=]. This is consistent with the phenomenon in our case where systolic pressure differences were significant between IBP and NBP when obtained from upper and lower limbs. Considering this phenomenon, although both dorsalis pedis artery and radial artery are peripheral arteries of the same level, the dorsalis pedis artery is farther from the heart than the radial artery, and the dorsalis pedis artery diameter decreases distally, while radial artery diameter does not change in this way. However, Gao et al. obtained IBP significantly lower than NBP when comparing dorsalis pedis artery IBP with ipsilateral posterior tibial artery NBP at the ankle. This result shows obvious differences compared with the comparison between invasive radial artery and noninvasive brachial artery in the upper limbs. This may be related to patient disease conditions, stable condition of elective surgery patients, and anesthesia medication use during general anesthesia.

Our patient had a BMI of kg/m2, belonging to the obese category with thick limbs, especially lower limbs showing an obvious "cone shape." Thick lower limbs can lead to insufficient cuff size causing falsely high blood pressure readings. Therefore, we could not perform comparison between ipsilateral lower limb dorsalis pedis artery IBP and posterior tibial artery NBP at the ankle.

When IBP and NBP acquisition sites are between upper and lower limbs, differences exist. So, what about comparisons of IBP and NBP differences between ipsilateral and contralateral limbs? Wax et al. conducted experiments simultaneously measuring IBP and NBP in anesthesia records, showing that when IBP and NBP measurements were on the ipsilateral or contralateral side, the relationship did not change significantly over time, and there were no significant differences between left and right measurement sites. Therefore, differences exist between IBP and NBP at different measurement sites, with significant differences between upper and lower limbs, but no significant differences between ipsilateral and contralateral limbs, similarly manifested in more obvious differences between invasive and noninvasive systolic pressure.

Blood pressure is one of the most commonly measured vital signs, especially in intensive care unit (ICU) patients, and can be measured noninvasively or invasively. For electrical injury and amputation patients, blood pressure acquisition is difficult. No relevant reports have been found comparing IBP and NBP in such patients. However, the differences between IBP and NBP in this case caused confusion for clinical observation and treatment, and reported results in existing literature also vary. Therefore, it is necessary to clarify the relationship between the two. This study suggests that when monitoring IBP and NBP, other vital sign results, condition changes, and patient complaints should be combined to assist clinical treatment. IBP and NBP cannot be simply substituted for each other to guide clinical treatment and nursing care.

Based on literature analysis, differences exist between IBP and NBP, with systolic pressure showing more significant differences. The difference value between the two ranges from - mmHg, a difference that deserves clinical attention. Factors causing differences between the two are summarized as: disease condition, different measurement sites, stress status, shock, vasoactive drugs, anesthetic drugs, etc. The main influencing factors between IBP and NBP, difference values, and correct interpretation of the clinical significance of differences between IBP and NBP require further clinical exploration.

Conflict of Interest Statement: The authors declare no conflict of interest in this article.

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