

CLINICAL AUDIT

A three year prospective audit of 212 presentations to the emergency department after electrical injury with a management protocol

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Significant numbers of presentations to the emergency department were found to relate to low voltage electrical injury, for which there was no widely accepted management protocol. It was decided to examine the outcome of patients after low voltage electrical injury with particular reference to electrocardiogram (ECG) changes and to evaluate a protocol for managing these injuries in order to optimise the management of patients after electrical injury. A prospective observational study was done over three years of 212 consecutive presentations to the emergency department of Mount Isa Base Hospital with a four year follow up after implementation of the revised protocol. In 4% of patients, early transient conduction abnormalities were seen after low voltage electrical injury. Admissions for cardiac monitoring were reduced dramatically with no resultant ill effects. Asymptomatic patients with a normal ECG on presentation do not need ECG monitoring after low voltage electrical injury. Patients with significant symptoms or ECG changes should be admitted for monitoring and observation. In view of the high proportion of workplace related injuries occupational health measures such as "triple gloving" should be mandatory for high risk groups.

Electrical injuries can be divided arbitrarily into high and low voltage; high voltage injuries are those exceeding 1000 volts, although ultimately it is the flow of current (amps) that determines the level of injury. On average there are 76 fatalities each year in Australia from electrical injury (Australian Bureau of Statistics). This number may be increasing as safety guidelines are being lowered to minimise costs,¹ since most electrical injuries are workplace related. Serious injury and death after high voltage injuries are well characterised; ventricular fibrillation is thought to be the commonest cardiac cause of death.² The management of patients with a spectrum of injuries after low voltage injury is less clearly established. Tissue damage is unusual, save for minor arc burns at points of skin contact, and usually there are few symptoms after the initial shock. While minor skin burns may conceal major structural damage beneath the skin, this is rare after a low voltage injury. A particular concern relates to cardiac rhythm disturbances. Some studies recommend cardiac monitoring after any electric shock,³⁻⁵ while other studies do not support this position.⁶⁻⁸

In late 1992, after an electrical injury in an employee who developed a transient but symptomatic bradycardia, a large local employer changed its policy. It began to refer all victims of electrical injury to hospital for cardiac monitoring. Prompted by a substantial increase in cases presenting to the emergency department, it was decided to conduct a prospective study of patients presenting after electrical injury.

Several sources were used to develop an initial management protocol for electrical injury, so that all patients had an electrocardiogram (ECG) at presentation and a repeat ECG after six hours of cardiac monitoring. If the patient remained well during cardiac monitoring, and serial ECGs showed no significant features, they were discharged. After discharge, patients were advised to assume light duties for an arbitrary period of seven days. In those patients with symptoms or ECG changes after electrical injury, appropriate management was instituted. Patient outcomes over the three year prospective data collection period were reviewed. In particular the

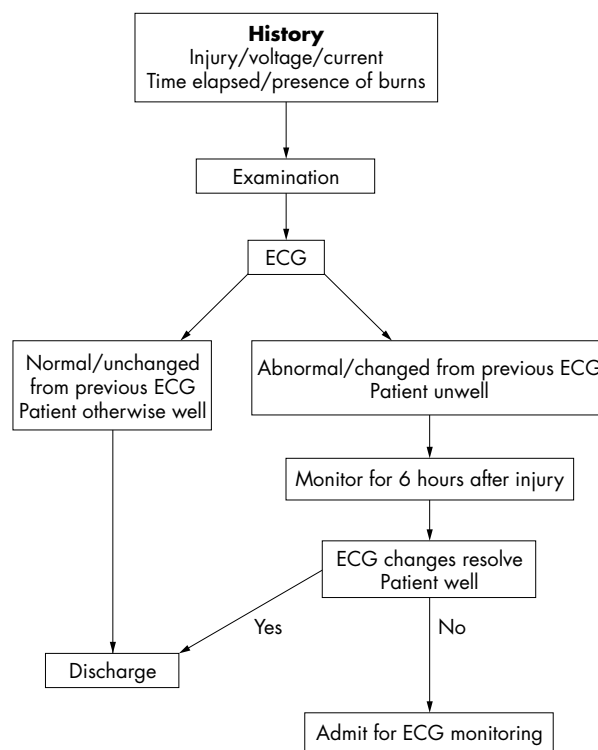


Figure 1 Management of patients after low voltage electrical injury.

mandatory six hour monitoring period was examined. Admitting patients for cardiac monitoring has considerable resource implications for both the health system and the employer. Over the subsequent four years, hospital admissions were monitored for adverse outcomes from the application of the revised protocol (fig 1).

SUBJECTS AND METHODS

The local employer's occupational health team was informed of the planned study. During the study period, the emergency department operated a manual triage book. Any presentation involving an electrical injury was recorded in this book and a data collection form completed. This form included demographic information (including age, occupation, and gender), the circumstances of the injury, the voltage (if known), and the presence of any contributory factors, such as water at the scene (which by lowering resistance increases flow of current). Each patient was managed according to the electrical injury protocol. At the conclusion of the initial three year study period (from March 1993 until February 1996), the data were analysed and the patient medical records reviewed with particular attention to serial ECGs and any evidence of complications. The protocol (fig 1) was applied in the subsequent four years, February 1996 to January 2000, and adverse outcomes were monitored.

RESULTS

There were 212 presentations between March 1993 and February 1996, involving 202 patients. On chart review, 16 patients where electrical injury was recorded in the triage book had had no direct contact with an electrical source. Excluding these cases from analysis left 196 presentations involving 186 patients. The mean age was 25 years; 90% of the presentations were in males. In 190 (97%) cases, the patients were admitted for six hours of monitoring with ECGs on presentation and before discharge. In four (2%) cases patients were discharged from the emergency department directly, because they presented many hours after the initial injury. Two (1%) patients took their own discharge against medical advice. In 159 (81%) cases the injury occurred at work, while 31 (16%) cases occurred in the home, and two (1%) cases elsewhere. In four (2%) cases the place of injury was not recorded.

There were no fatalities in this series and no patient represented with cardiac arrhythmias after discharge. Eight (4%) patients were admitted for cardiac monitoring. In two (1%) patients, the initial ECG showed incidental and previously undiagnosed Wolff-Parkinson-White syndrome (incidence in the general population approximately 1.5 per thousand⁹). Transient symptomatic bradycardia developed in six (3%) patients, the heart rate falling to 34–40 beats/min. In four patients this was due to first degree heart block, and two patients had transient complete heart block. No patient required pacing; atropine was effective in restoring heart rate in three symptomatic patients with bradycardia and hypotension.

A range of other ECG abnormalities was noted in 74 (37%) patients, many of a non-specific nature which probably existed before the injury. Findings included saddle shaped ST segment elevation suggesting pericarditis, particularly in chest leads V1–4, partial right bundle branch block pattern, ventricular extrasystoles, and changes in configuration of P waves and T waves. In 28 (14%) patients QT prolongation was noted, in only three patients did this persist beyond six hours, resolving by 24 hours.

Eighteen (9%) patients had minor burns at the point of current arcing to the skin; one patient had severe bruising to biceps caused by muscle fibre damage during tetanic contractions. Two patients were pregnant at the time of their injury, both subsequently delivered normal infants. Of the 159 work related injuries, 49 (31%) were clearly related to welding, and 20 (14%) were in electricians. In 63 work related cases (32%) the presence of water at the scene of injury was recorded. In the subsequent four years after the implementation of the revised protocol there were no representations with conduction abnormalities.

DISCUSSION

ECG monitoring after electrical injury

The main focus in this study was to consider the need for six hours of ECG monitoring after electrical injury. The results from 196 presentations suggest that ECG monitoring is not required when the patient is otherwise well and the initial ECG is within normal limits. This conclusion is further validated over the subsequent four year period when the protocol was in operation. In 196 presentations there were eight episodes with ECG abnormalities requiring ongoing ECG monitoring (compare with Bailey *et al* who found a single ECG abnormality in 96 patients, thought to be unrelated to 120V injury,⁷ and Housinger *et al* where 5/16 patients had ECG abnormalities¹⁰).

Purdue and Hunt state that monitoring after electrical injury is "a luxury based on remote probabilities", after 48 consecutive patients were admitted after *high* voltage injuries when the initial ECG on presentation was normal.¹¹ The criteria proposed for ECG monitoring included loss of consciousness or documented arrhythmias in the field, and ECG abnormalities on admission.¹¹ However other studies recommend most or all patients are monitored for a specified time regardless of the voltage of the injury.^{3,5} The results from the present study suggest that in the absence of ECG changes at presentation after low voltage electrical injury, the patient if otherwise well can safely be discharged home without undergoing ECG monitoring.

A range of ECG changes was found after electrical injury. Those causing symptoms were bradycardia resulting from transient first degree or complete heart block. Some patients were found to have transient QT prolongation, of particular interest since prolonged QT syndromes are recognised as a risk factor for sudden death due to ventricular fibrillation.¹² The cause of this prolongation is unclear, electrical injury is not listed in the causes of acquired long QT syndromes,¹³ although one case report described lightning injury causing prolongation of the QT interval.¹⁴

Delayed arrhythmias and exertion after electrical injury

Whether patients should avoid exercise and heavy manual work for a period of time remains controversial. It has been suggested that the presence of acidosis and excess sympathetic drive (caused for example by vigorous exercise) may predispose to arrhythmias in such patients.³ Cunningham found in his survey of 56 directors of emergency departments around Australia (with 36 respondents) there were no cases of delayed arrhythmia.⁸ One unreported case, however, is known where an electrical injury 48 hours earlier was implicated in a fatality after return to full manual work that day. Jensen *et al* describe three cases of delayed arrhythmia in patients after electrical injury, in two of whom the voltage was within the domestic range,³ however as discussed above, no ECG was taken immediately after electrical injury because the patients presented late. One patient developed recurrent ventricular fibrillation, another had runs of ventricular tachycardia, and the third had ventricular parasystoles. Endomyocardial biopsies in two patients showed patchy myocardial fibrosis, thought to have served as an arrhythmogenic focus. It is difficult to draw general conclusions from these three cases without an initial ECG or assessment, thus although the onset of symptoms may have been delayed by 8–12 hours, it is unlikely that an ECG would have been normal immediately after the electrical injury. The value of measuring the creatine kinase-MB fraction as a marker for myocardial injury is controversial, with authorities suggesting that it is of limited specificity^{10,15}; for this reason it was not used as part of the assessment in this study. The authors are aware of no studies using troponins as markers for myocardial damage after electrical injury, though they are highly sensitive in this role. As stated above there were no cases where delayed arrhythmias were

diagnosed in this study and no patients represented with symptoms.

Occupational health considerations

The high number of work related injuries in this study invite a focus on workplace health and safety. The introduction of basic safety measures such as triple gloving and the widespread use of residual current devices (which could save up to 66% of deaths after electrical injury)^{16,17} are of central importance in preventing these injuries. Many of the welders seen in the emergency department after electrical injury report receiving several "minor" shocks each day in the course of their employment; certainly this is a high risk group of workers.

In summary, a protocol has been developed for the management of patients after electrical injury (fig 1). Only those patients with symptoms, injuries, or initial ECG changes (including QT prolongation) need to be admitted for cardiac monitoring. In the four years since implementation of this protocol there have been no deaths or representations as a result of electrical injury. By admitting for cardiac monitoring only those victims of electrical injury who are at risk of developing further rhythm disturbances, the use of ECG monitored beds has been reduced. Whether victims of electrical injury should be confined to light duties for a period after electrical injury remains unresolved. The results of this study led the local employer to adopt the protocol for workers involved in electrical injury, thus improving bed utilisation and avoiding unnecessary down time for its employees.

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