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A stab in the dark: Design and construction of a novel device for conducting incised knife trauma investigations and its initial test

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ABSTRACT

Knife attacks are commonly seen in Australia and other countries. During forensic investigations the force with which a wound was inflicted is often questioned. The ability to examine resultant trauma and particular weapons at different forces with an experimental device may lead to better interpretations of knife wounds. The objective of this study is to design, construct and test a device to analyse the characteristics and forces involved in knife attacks, particularly incised wounds. The mechanical variables (e.g. force, angle, knife geometry) involved in knife attacks have been considered to design and construct a suitable device which allows these variables to be systematically controlled and varied. A device was designed and constructed from mild steel. This included a pivoting arm and instrumented knife holder. The arm has adjustable angle and weight so that knives can be operated at different calculated forces. A device was successfully constructed and the repeatability of incised knife trauma and its characteristics in skeletal tissues were investigated. A device which allows reproducible and controlled experiments with knife wounds will be advantageous to forensic investigations. In particular, in determining forces and types of weapons associated with particular wounds, identifying or eliminating suspected weapons and more accurately answering the common question: How much force would be required to cause that particular wound. This could help to characterise the perpetrator. The device can be altered to be used in the future to investigate trauma caused by other weapons.

1. Introduction

Sharp force trauma is the leading cause of homicidal deaths in Australia, United Kingdom and Sweden [1–3]. In Australia, the most common weapon used is a knife (92%) [3].

In a homicide context, knives are classified as sharp force instruments where the trauma caused is a result of a force that is both dynamic and acutely focused. The wounds inflicted by knives penetrate through skin, subcutaneous connective tissue, muscle and damage bone in various ways, depending on the angle and impact force of the weapon. The wounds are characterised by a well-defined traumatic separation of tissues, which occurs when a sharp edged or pointed object, such as a knife, comes into contact with the skin and underlying tissues [4]. Knife wounds can be subdefined into three categories: incised wounds, stab wounds, and chop wounds, and this study will focus on incised wounds. Incised wounds differ from the other wounds as the force acts tangential to the surface. Such injuries are often found on the upper limbs of the victims as they attempt to defend themselves [5].

Interpretations of trauma are particularly important given the fact that trauma accounts for the majority of suspicious deaths. Skeletal trauma may provide the only information about the cause and manner of death if the body has decomposed [6,7]. Through careful analysis of cut marks on bones, it is possible to determine the cause of the mark and specify what weapon was used [6–8].

During investigations the degree of force with which a particular wound was inflicted is of interest. The resultant answer may be significant in identifying the perpetrator(s) and their intent to cause harm [9] as a greater force may be associated with a greater intent to cause harm. Forensic pathologists often describe the magnitude of force used in causing particular wounds in broad terms, depending on the penetration depth and damage; mild, moderate, severe [9,10]. However, having the ability to replicate knife attacks, in particular incised wounds, with a device which allows force to be measured may improve the descriptions and identification of particular wounds and the forces involved in causing them.

Previous attempts at constructing devices to investigate knife trauma have used drop tower tests or involved human participant

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trials and/or author inflicting wounds to investigate knife trauma, mainly stab wounds [11–13]. Kaatsch et.al., [14] investigated, experimentally using porcine cadavers, stab wounds using a measuring device allowing objective assessment of the influence of the speed and the forces of stabbing on the bones and soft tissues.

This paper is aimed at studying, systematically, incised wounds. It describes the design and construction of a device which allows accurate, controllable and reproducible measures of the characteristics and forces of incised wounds. This device may be applicable in forensic investigations to aid in identification or eliminating a suspected knife, estimating force particular wounds are made with and have the ability to be manipulated to benefit investigations in other sharp force trauma and blunt force trauma e.g. screwdrivers. The ability to alter the force in a test rig may allow better conclusions to be made on the common question of what degree of force was used to create a particular wound.

2. Materials and method

2.1. The device

A pivoting arm device was designed and constructed, by the first author, to allow for the replication of the arc motion of a perpetrator's arm during an overarm knife attack. This design does not include all joint movements of the upper limb, such as lateral movement. The device does allow the mass and angle to be altered, which consequently alters the force and eliminates author or human participant biases. The location of the specimen cradle allowed the knife to pass under the specimen and make contact in a tangential motion, rather than a stabbing motion, thus creating incised wounds.

An instrumented knife holder was designed to securely attach the knife to the pivoting beam. This detachable design allows modification to occur to investigate blunt weapons and other sharp force weapons.

The device (Fig. 1) was constructed out of mild steel for strength and sturdiness. Specific dimensions of the structure can be seen in Table 1. All steel was cut to size and desired joining angles cut with an angle grinder and welded together with an arc welder. Two ball bearings were located at the centre point (750 mm) of the pivoting arm. These bearings had a maximum load of 2.0 kN. The instrumented knife holder was located 710 mm (average length of a human upper limb) from the pivot point. This knife holder was composed of flat steel plates welded together (dimensions varied depending on knife size). High tensile bolts were used throughout the device. Open ended beams were capped with a plastic square cap of same dimensions as beam. Safety mechanisms were put in place to prevent unwanted injuries and a release mechanism allows the pivoting beam to be remotely released from a safe distance.

Table 1
The dimensions of the individual steel sections creating the device.

Section	Length (mm)	Steel beam (mm)
Base	1500 × 1000	40 × 40 × 4 square
Cross section 1	910	40 × 40 × 4 square
Cross section 2	675	40 × 40 × 4 square
Vertical beam	900	40 × 40 × 4 square
Vertical supports × 3	1000	25 × 25 × 3 square
Pivoting arm	1500	40 × 40 × 4 square
Specimen Cradle bar	975	30 × 30 × 3 square

2.2. Force measurement

A theory based approach was used to determine the force at various angles of movement. This was based upon a pendulum swing and the force at the base of the pendulum's swing, which is applicable to this device as the arc of the swinging arm followed a pendulum's swing.

The force was determined through Newton's second law of motion:

$$F = ma$$

F = force (N); m = mass (kg); a = acceleration (m/s^2)

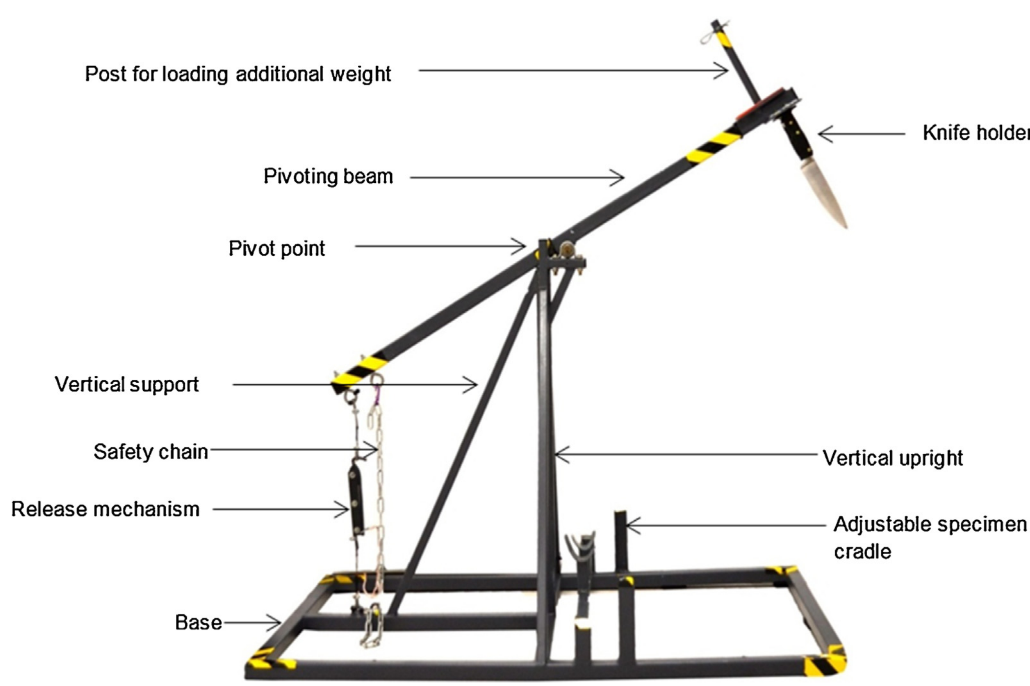

Fig. 1. The device with labelled components. Safety mechanisms designed to prevent accidental release of pivoting beam and a trigger mechanism allows remote release.