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Computed tomography of scalp embedded gravel: Differentiation between falling and kicking

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ABSTRACT

In the case of a survived head injury of a 39 year old man, kick versus fall as mechanism had to be discerned. On top of conventionally used medicolegal findings, clinical computed tomography (CT) scans were evaluated. There, dense particles at the back of the head were scattered on and in the skin, around the region also likely to be the center of an impact related skull burst fracture. Experiments then were conducted to discern falling, kicking and scrubbing, based on gravel particle details, using suitable model substrate materials. Particle size and count were larger in falls without scrubbing than in kicks also because soles may not retain heavier or larger gravel particles. Based on chemical composition obtained through EDS (energy-dispersive X-ray spectroscopy), gravel particle mass attenuation coefficient was determined, linearly correlating with effective CT attenuation of scalp particles and bone and skin materials. Gravel particle size showed to be a stronger evidence in the distinction of fall versus kick than skin and brain morphology. Clinical CT can be a valuable asset in reconstructive forensic medicine.

1. Introduction

A man sustained head injuries in contact with a sealed (or paved) road in winter, due to which he then was admitted to hospital. We were given the task of conducting a reconstructive analysis of the head injuries for the differentiation of falling versus kicking on the basis of the hospital CT (Computed Tomography) images.

We determined the thickness of the facial skin and scalp in order to localize possible regions of swelling. We did this by visualizing the minimal difference between skin and bone correlated CT data using 3D isosurface (see Fig. 1C and D). There, we noticed round artifacts predominantly at the back of the head. Due to the questionable history of this particular incident, we suspected gravel particles as cause for these peculiar image artifacts. Gravel is frequently used on unsealed and sealed paths or roads to increase vehicular tyre or shoe sole friction, particularly in winter in northern European countries [1].

In medicolegal considerations, differentiation of blunt trauma – as in differentiating between a fall or a kick – conventionally is approximated using the distribution of injuries across an injured person [2,3] or on purely biomechanical considerations [4]. Soil particles are known as potentially infectious risk [5] or as an occasional radiological oddity [6], but so far and to the best of our knowledge, morphological aspects of soil particles have not been employed as evidence to discriminate blunt trauma causes.

We attempted to establish whether identified X-ray dense inclusions in the CT representation of the scalp could be plausibly linked to gravel particles and whether on the basis of measurable properties of these particles, a contribution towards further discriminating between falling and kicking could be made in this particular instance.

For this purpose, a series of experiments were conducted in order to provide insight into gravel particle CT properties. Subsequently, for both particle and conventional injury morphology, evidential values were determined for this case.

1.1. Case description

A 39-year-old man was involved in a physical dispute outside a restaurant that took place in the early morning hours in February 2002 (cold and dry weather conditions), and suffered head injuries as a consequence.

He was admitted in a hospital about one hour after the incident. Initially, significant blood alcohol content (1.93‰ w/w) and reduced blood coagulation due to liver disease were diagnosed. Hospital notes indicated that his head had not been scrubbed or cleaned particularly well before CT scanning. Emergency CT head scans were obtained on a Marconi Twin-7180 Mx8000 CT scanner; acquisition parameters contained a pixel spacing of 0.48 mm and slice thickness of 0.60 mm with 120 kVp and 240 mAs.

An occipital skull burst fracture (Fig. 1A and B) as well as a midline shift due to a subdural hemorrhage was diagnosed;

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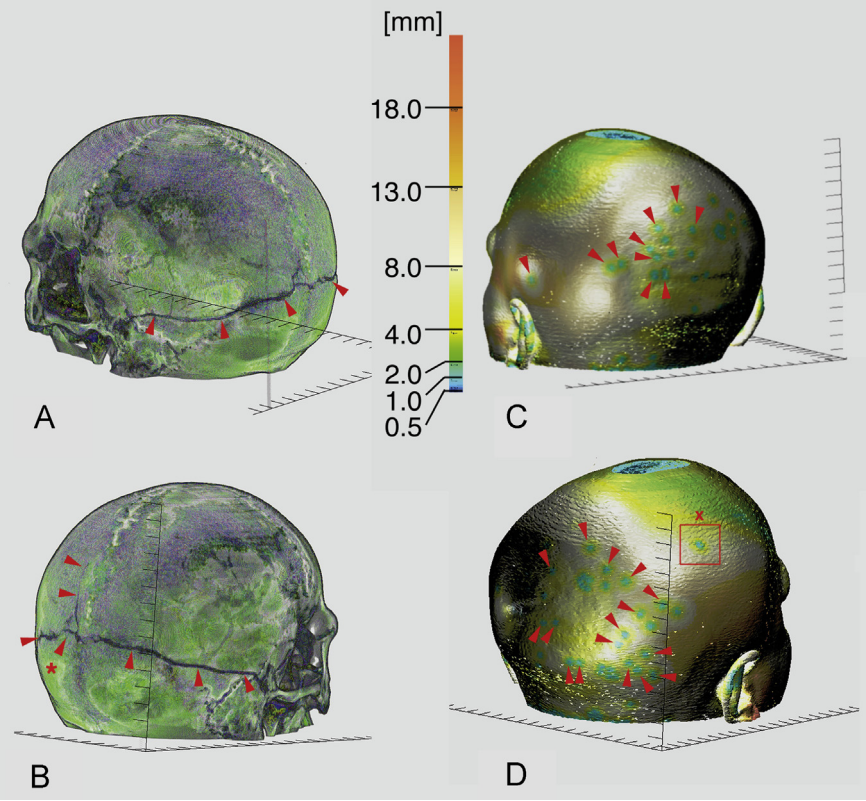

Fig. 1. Case-based reconstructions from hospital CT data: macroscopic level. *Occipital skull burst fracture* containing three hairlines (*red arrows* in A and B), two radiating laterally into the petrous bones, one radiating upwards, thus placing the burst fracture center at the occiput (*red arrow/star* in B); *Particles*: minimal distance map (see color bar for soft tissue thickness) between iso-surfaces representing skin (−50 HU [Hounsfield units]) and bone (250 HU) showing round artifacts (*red arrows*), representing a range of very short distances to what emerged to be small particles; one particular particle (D: rectangle labelled *x*) is detailed in Fig. 2. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)

subsequently, the neurosurgeon removed the subdural hemorrhage and cauterized a ruptured bridging vein while noting frontal cortical contusions (so-called 'contre coup' lesions). The man survived this incident but retained a degree of disability, particularly related to disturbance of vision and gait.

Witness' statements of the physical dispute were controversial: according to two accounts, there had been an initial fall on the back of the head, followed by a second fall on the back of the head from a lesser height. Two other accounts alleged that he had been viciously kicked against the head while lying on the ground; the ground at the scene contained a sealed street with unsealed patches containing gravel.

Due to this controversy, investigating authorities referred the hospital record and CT data to us for reconstructive analysis. As part of evaluating medical records and data, we first suspected (Fig. 1) and then confirmed (Fig. 2) the presence of particles in the scalp before experimentally evaluating various forms of impalement (Figs. 3, 4, and Table 1), putting results in context of rock analysis (Fig. 5, Tables 2 and 3) and ultimately deriving evidential values from this (Fig. 6, Tables 4 and 5), based also on the chemical composition of the rocks that were most likely impaled (Fig. 7).

2. Method and material

2.1. Experiments

2.1.1. Scalp and head simulation substrates

In order to investigate gravel impaction into scalp due to falling or getting kicked we simulated the scalp and skull using substrates.

Particle transfer depends on the characteristics of the surfaces involved, and energies characterizing the impact of head against various surfaces are determined by weight, speed and relative surface geometry of colliding objects [7].

We chose pig skin rather than an artificial material in order to test gravel particle pickup during realistic impacts; pig skin samples were legally purchased from the spoilage of the local slaughterhouse; no animal was killed for the purpose of this study and no research was performed on living tissues, organs or organisms.

We chose a bowling ball (4.65 kg weight, 22.5 cm diameter) to approximately match weight, shape, size and curvature of an adult human head [8,9] which we additionally fitted with thin metal rods to allow for proper fixing of skin samples.

2.1.2. Experimental injury with gravel impaction

Gravel was impacted into the pig skin that had been fixed to and stretched over the bowling ball in two ways: falling and kicking. After this, all samples were tightly sealed into plastic bags for scanning.

Falling: Skin was crushed between the ball that fell from around 1.80 m height and an unsealed road covered by gravel (see Fig. 3a); the test was done twice: in one instance, the skin sample was sealed in a plastic wrap immediately (experiment #1, Fig. 4A and B), in the second instance, the skin sample was vigorously scrubbed before sealing it (experiment #2, Fig. 4C–E).

Kicking: A boot containing a structured rubber sole that was covered with gravel after walking on the unsealed road (see Fig. 3 b) was violently kicked against the skin fixed to the ball that was lying firmly on the ground, being held by an assistant who also made sure the skin surface would not touch the ground; the first