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Technical note

Development of a radiographic technique for porcine head ballistic research

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A B S T R A C T

Introduction: The porcine model shows structural features comparable to that of humans and are routinely used within research, due to the ethical, legal, and practical use of post-mortem human samples. Methods for obtaining high quality and comparable reference data using standardised acquisition protocols are essential.

Methods: The decapitated heads of three adult white sows were subjected to radiographic imaging before and after cranial trauma (9 mm, Heckler and Koch MP5). Digital radiographs were generated using a Siemens MULTIX TOP system with an Agfa digital detector, with foam blocks and sandbags as ancillary equipment. An iterative approach was adopted by the authors to generate reproducible radiographic views from two perpendicular angles. Specimens were kept at 5 °C and wrapped in polythene bags to reduce the impact of putrefaction.

Results: Standardised head radiography technique was developed for superior-inferior and lateral views demonstrating porcine anatomy. Key parameters included: automatic exposure control for tube current (~4 mAs), tube voltage of 73 kVp, 100 cm source to image receptor distance, and an anti-scatter grid. Slight variances in specimen morphology, developmental status, and soft tissue changes did not affect imaging outcomes.

Conclusion: The technique and positioning proposed in this study allows for the acquisition of high quality and reproducible radiographic images for comparable ballistic research datasets. Specimen positioning and centring of the primary beam may be applied across porcine breeds, although individual radiographic parameters may differ according to equipment specifications and specimen size.

Implications for practice: Development of a reproducible radiographic technique of porcine heads in forensic and veterinary research.

Introduction

The superiority of computed tomography (CT) for post-mortem imaging is widely accepted for ballistic imaging, with examples in the detection of forensic evidence[1] and reconstructing the manner of death.[2] In contrast, conventional radiography is predominantly utilised as a screening tool.[1,3–5] Despite the benefits of CT, radiography persists as an indispensable forensic tool offering relatively cheap, quick imaging with lower data burdens and easier use.[6] Within gunshot ballistic research, this may encompass the effect of ammunition type, bullet trajectory, and fragmentation thereof, which is used for reconstructing events at a scene and, therefore, of importance within the criminal justice system.

To generate meaningful sample sizes and impose constants and variables, researchers may elect to use alternative models such as the pig to simulate real-world conditions. Porcine models have been used to replicate the human skull[7] and investigate gunshot injuries in the past,[8–11] due to broad similarities in structure and comparable density of soft/hard tissue. The porcine model has also been used in surgical training[12] and blast injury research,[13] with similar parietal skull thickness to that of humans. However, despite the widespread use of porcine models in research, there is a lack of guidance regarding cranial radiographic techniques within both

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forensic and veterinary literature. This is a limitation within forensic investigation where it is important to have a suitably large database as a reference to understand natural variation, particularly if this model is to be used for research purposes. In this paper, the authors present a radiographic acquisition protocol for porcine heads using conventional radiography. This aims to address two research priorities within forensic radiography: comparable forensic reference data and improved image quality and consistency.[11] This brief account presents the iterative process used by the authors to develop and refine the radiographic technique which may facilitate further research.

Materials and methods

The porcine breed selected for this research was the Large White sow, with an age range of 6–7 months at the time of slaughter. Aside from being locally available for meat consumption, the breed has been used in previous studies as a model for human anatomy.[11,12] The pigs were slaughtered by stunning using electric current and subsequent bleeding in accordance with The Welfare of Animals (Slaughter or Killing) Regulations 1995.[14] Research was approved by local ethics committee (ETH2021-0172). Three heads were sourced from a butcher with an incision at the skull base, detaching the cervical vertebrae but retaining much of the soft tissues around the neck, as per commercial butchering processes. Specimens were double bagged using polythene, for hygienic purposes, and stored at 5 °C within a temperature-controlled room to delay decomposition.

To illustrate the retention of ballistic material, each head was subjected to a single shot from a 9 mm round, fired at short range from a Heckler and Koch MP5 to the left temple region. Both range and round type allowed for improved shooter accuracy and therefore reproducibility in replicate shots. All practical procedures involving the use of firearms were performed by trained professionals. A Siemens MULTIX TOP system fitted with an Agfa Platinum digital detector was used for the imaging, utilising a table Bucky, along with radiolucent foam positioning aids. Previous studies have presented superior-inferior and lateral radiographic views of porcine heads,[7,15] but lacked instructional content for their acquisition. As such, a trial-and-error approach was used for the development of these radiographic techniques, with adjustments made to tube voltage and current for optimal image quality. Assessments of image contrast, data density, noise, and sharpness were undertaken by an experienced clinical radiographer, based upon visualisation of cortical outlines, trabeculae pattern, and air-filled cavities. Image analysis was performed using RadiAnt DICOM viewer (RadiAnt Viewer version 2021.1, Poznan, Poland)[16] on medical-grade screens.

Results

Two radiographic views perpendicular to one another were developed to demonstrate evidence of ballistic damage, retained bullets, or fragments thereof. Superior-inferior and lateral views of the decapitated porcine heads were obtained. Specimen positioning, radiographic exposure values, and equipment variables are shown in Table 1, with example radiographs in Figs. 1–2. This was supplied to a volunteer diagnostic radiographer to independently test accuracy and comprehensibility of the radiographic technique, with a successful outcome. The alignment and precise superimposition of dentition on the lateral view proved instrumental in ensuring accurate and repeatable results (Fig. 3). The use of a table Bucky with a free-floating tabletop allowed ease of movement, adjustment, and re-imaging. This was combined with the benefits of an automatic exposure control (AEC) chamber and the anti-scatter grid to improve image quality when compared to direct contact with the digital detector. Polythene bagging of the heads, although necessary for cleanliness, introduced additional difficulties in positioning as surface anatomy was visually obscured. To combat this, physical manipulation of specimens was required, with the utilisation of the nostrils as a point of reference to ensure parallel or perpendicular alignment of anatomy to the image receptor.

Table 1
Radiographic technique.

	Superior-inferior view	Lateral view
Source to image receptor distance	100 cm	
Tube voltage	73 kVp, broad filament	
Method of current control and duration	Table bucky using central automatic exposure control chamber Average exposure ~4 mAs	
Anti-scatter technique	Stationary table grid	
Collimation	To include soft tissue borders	
Anatomical marker	Placed to identify laterality	
Specimen positioning	Placed in anatomical neutral position with distal portion of snout elevated to bring hard palate (palatum durum) parallel to image receptor. Mouth closed with mandible aligned to maxillary teeth.	Placed on flank with snout elevated to bring vomer (septum nasi) parallel to the image receptor. Nostrils aligned vertically to ensure neutral position of anatomy.
Centring point	In the midline at a point equidistant from snout to posterior extent of head severance.	Second upper molar or a point bisecting maximum length and height of specimen flank.

Discussion

Radiography remains an indispensable tool within forensic practice and research[17] due to the speed of image acquisition, lower

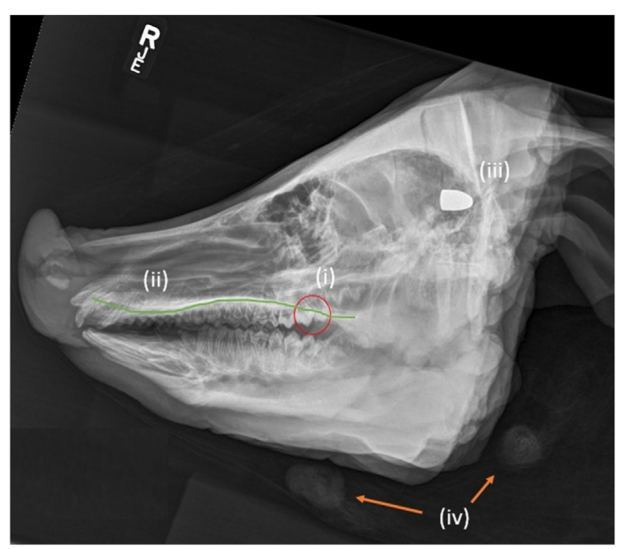

Figure 1. Lateral radiographic view of porcine head showing (i) centring point at second upper molar (red circle), (ii) hard palate (palatum durum) used as a point of reference for superior-inferior view (green line), (iii) retained bullet and (iv) polythene bag image artefact (orange arrows). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

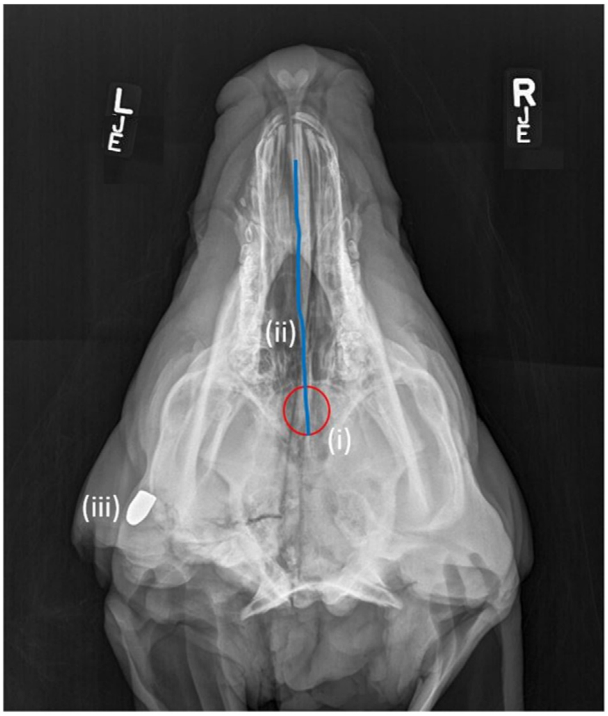

Figure 2. Superior-inferior radiographic view of porcine head showing (i) centring point (red circle), (ii) vomer (septum nasi) used as a point of reference for right lateral view (blue line) and (iii) retained bullet. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

cost, and training needs. Well-established acquisition protocols within forensic science have proved vital for the reliability of evidence collected and acceptance within the criminal justice system.[18–20] However, a paucity of literature for porcine head radiography impedes such advancement, particularly as scientific enquiry relies upon standardised methods of data collection. This ensures both reliability of results and the generation of comparable datasets for future investigative purposes. The radiographic technique presented within this study shares similarities with previously published examples of porcine head radiography,[7,15] with the novelty of being the first time the acquisition protocol has been detailed. With the lack of CT equipment or suitably trained staff, radiography may offer a realistic alternative option for emerging research or suitably framed research questions.

Within diagnostic radiography, examination-level research typically concerns the development or refinement of radiographic techniques to improve patient care. In the context of evidence-based radiography, this encapsulates empirical evidence, experience-based knowledge (of the practitioner), and service user experience.[21,22] In the absence of prior guidance or empirical evidence, this research acknowledges a reliance upon first-hand experience to generate and propose an imaging protocol. Parallels with human imaging are possible though, including the use of foam pads to ensure neutral positioning of the head and the superimposition of anatomy.[23,24] Similarly, tube voltage was within expected values for human comparison, although the use of AEC may vary due to subject size. The application of an anti-scatter grid served to improve image quality by reducing unwanted noise, similar to previously published research.[25] At an elementary level, the provision of two views at perpendicular angles provided sufficient anatomical detail and confidence to locate ballistic material. The ability to discern trauma to bone and soft tissue was more problematic though, given the complexity of the anatomy and a lack of porcine radiography reference material. Furthermore, radiography has been shown to miss 19.1% of skull fractures in a retrospective (human) study comparing radiographical reports and autopsy findings.[26,27] Another consideration is post-mortem putrefaction of soft tissues, which may also mislead the investigator due to areas of radiolucency caused by gas accumulation.

Several limitations were experienced by the authors of this study. The handling of severed heads and the translation of clinical (human) radiography required unique problem-solving skills not encountered before. The assessment of radiographic images did not adhere to predefined criteria as published elsewhere,[28,29] instead relying upon the substantive clinical experience of a diagnostic radiographer and therefore subjective opinion. Future research and refinement of the technique may benefit from a more robust method of image analysis. Lastly, pig morphology differs between breeds with a vast array of variations in soft and hard tissue appearances. This, along with variances in butchery practices, may impede comparable datasets in future studies with porcine radiography. Equally, the authors are aware that different imaging equipment may result in a variation in image quality. In such instances, the radiographic technique presented here may require adaptation to achieve the same outcomes.

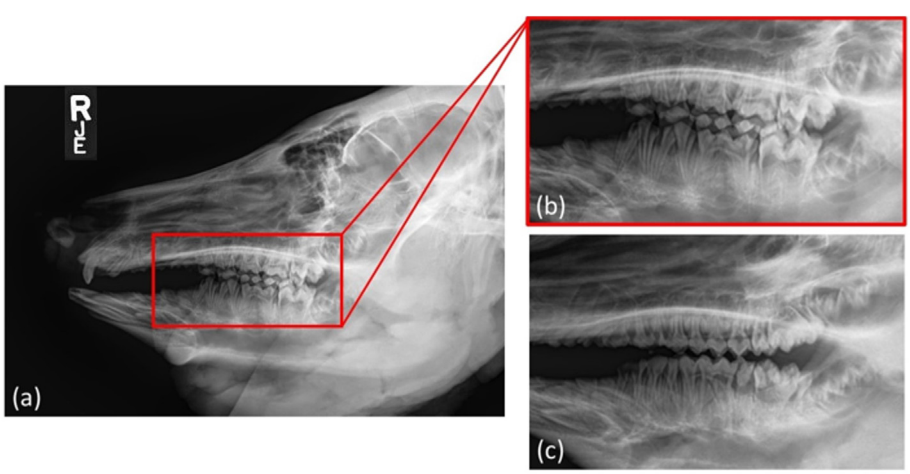

Figure 3. Radiographic alignment of dentition as an indicator of accurate positioning showing (a) Lateral view, (b) magnified area showing malalignment of dentition and (c) correct positioning with superimposition of dentition.

Conclusion

This study has developed a reproducible radiographic technique for porcine heads to aid research involving porcine heads, particularly within forensic science. Recommendations listed herein provide a standardised protocol for lateral and superior-inferior views, allowing comparable datasets in future studies both within and outside of forensic investigation. Finally, this study accepts the variability of pig morphology across breeds and variances in butchery practices for detaching the head. In such instances, the authors recommend adaptation of the radiographic technique to achieve the same results.

Conflict of interest statement

The authors have no competing interests to declare.

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