CQ20: What postmortem imaging findings are useful for age estimation?

Recommendation Grade: C1

Bones and teeth are relatively resistant to postmortem changes and are therefore useful for age estimation. In individuals up to around 25 years of age, the degree of skeletal growth and development can be used. In adults, age-related degenerative changes serve as indicators. However, as age increases, individual variation becomes greater, making precise age estimation more difficult.

Explanation

● Background

In the investigation of unidentified human remains, estimating biological profiles such as age, sex, stature, and ancestry is essential. Bones and teeth are commonly used for age estimation because they are relatively unaffected by postmortem changes. Age estimation in younger individuals is based on assessments of growth and development. In contrast, age estimation in mature individuals relies on the degree of age-related (degenerative) changes. However, such degenerative changes vary considerably between individuals due to factors such as hormones, genetics, biomechanics, and pathological conditions, making age estimation in adults generally less precise than in younger individuals[1–4].

● Imaging Findings

1) Age Estimation in Younger Individuals

For age estimation using bones, individuals up to approximately 25 years old are assessed based on the appearance and fusion of ossification centers and the degree of epiphyseal fusion[1,2]. The relationship between skeletal development and chronological age has long been studied using both direct observation and radiographic imaging[5–11]. However, there are still few studies that have evaluated these features using postmortem CT or MRI.

In dental-based age estimation, assessments are made using the degree of tooth calcification and eruption status[1,2]. The developmental chart of dental eruption presented by Schour and Massler[12] is widely recognized. Studies evaluating the accuracy of applying such developmental charts for age estimation have reported that charts created from data on populations closely matched to the target group provide relatively higher accuracy[13,14]. For Japanese individuals, data published by the Japanese Society of Pediatric Dentistry are available[15]. One widely used method for estimating age based on dental development stages is that of Demirjian[16,17]. However, some studies have reported that this method tends to overestimate chronological age[9,18]. The Willems method[19], which is a modification of Demirjian's, has been regarded as having a lower tendency to overestimate age, although some questions remain about its accuracy[20–23].

In recent years, the growing number of legal proceedings involving migrants and refugees has highlighted the impotance of age estimation in both legal and forensic contexts[24]. While the age of criminal responsibility varies by country, many countries define adulthood as 18 years or older. As a result, numerous studies have focused on determining whether an individual is over the age of 18. The Study Group on Forensic Age Diagnostics (Arbeitsgemeinschaft für Forensische Altersdiagnostik: AGFAD), primarily based in Germany, recommends a comprehensive approach involving physical examination, radiographic examination of the left hand, dental assessment (including radiographs and cone-beam CT), and CT imaging of the medial clavicular epiphysis[25 26]. For age estimation using the bones of the left hand, classification systems such as those by Greulich and Pyle[27] or Tanner-Whitehouse[28 29] are used. For the medial clavicular epiphysis, the Schmeling classification[30 31] and the more detailed Kellinghaus classification[32] are commonly employed. Alternative methods that avoid radiation exposure—such as low-dose CT, MRI, and ultrasound—are also being studied[33–37]. In addition, there are studies exploring age estimation based on bone density of the medial clavicle and the first costal cartilage[38]. The third molar is often used as an indicator for determining whether root development has been completed, which typically occurs after the age of 18[39–42]. The third molar maturity index (I3M) proposed by Cameriere has shown high sensitivity and specificity for distinguishing adults in white populations[43 44], and has also been investigated in other ethnic groups[45–47]. Further research has explored age estimation methods using imaging of the iliac crest, right knee, left elbow, and sternum[48–51]. There are also studies that have used 3D photography to construct facial prototypes for the purpose of age estimation[52].

2) Age Estimation in Adults

In adults, age estimation is based on age-related changes in bones and teeth[1 2]. In dry bone analysis, traditional methods have used features such as the degree of cranial suture closure, morphology of the pubic symphyseal surface, changes in trabecular structure of long bones such as the humerus and femur as well as the pubis, degenerative changes in articular surfaces of the ribs and ilium, degree of osteophyte formation, degree of tooth wear, and reduction in the size of the pulp cavity[2].

The relationship between skeletal aging and chronological age, similar to the evaluation of developmental stages in younger individuals, has long been studied through visual inspection and radiographic imaging. More recent studies using postmortem CT have proposed age estimation methods based on features such as cranial suture closure[53], interpubic distance[54], trabecular structures of the pubis and ilium[55], morphological changes in the pelvic bone[56], ossification of the sternum and ribs[57], and osteophyte formation in the thoracolumbar spine[58]. Three-dimensional visualization of bones using CT and laser scanning has also been explored as a tool for age estimation[59 60].

In dental-based approaches, many studies have reported the use of the pulp/tooth ratio, which changes with age due to secondary dentin deposition[61 62]. Specific methods include Kvaal’s technique, which uses linear ratios on two-dimensional radiographs[63]; Cameriere's method, which employs area ratios on radiographs[64]; and approaches using postmortem CT to compare volumetric measurements[65–69].

Additionally, complementary studies have investigated age estimation based on bone mineral density measurements using CT imaging of the pubic symphysis, femur, and thoracic vertebrae[70–72].

○ Literature Search Strategy and Selection (as of August 13, 2023)

【PubMed】

#	Search formula	Number of articles
1	(((((((((postmortem) OR post-mortem) OR "post mortem")) OR victim)) OR ((((refugee) OR asylum) OR migrant) OR immigrant))) AND "age estimation")) AND ((((((((((((((imaging) OR CT) OR "computed tomography") OR MR) OR "magnetic resonance") OR MDCT) OR MSCT) OR X-ray) OR "X ray") OR Xray) OR roentgeno) OR radiograph) OR radiography))	238
2	(((meta-analysis) OR systematic review)) AND "age estimation"	59

【医中誌】

#	Search formula	Number of articles
1	((((画像診断/TH or 画像診断/AL)) and ((FT=Y) and AB=Y and PT=会議録除く)) or (((X 線 CT/TH or X 線 CT/AL)) and ((FT=Y) and AB=Y and PT=会議録除く)) or (((MRI/TH or MRI/AL)) and ((FT=Y) and AB=Y and PT=会議録除く)) or (((X 線/TH or x 線/AL)) and ((FT=Y) and AB=Y and PT=会議録除く))) and ((年齢の推定/TH or 年齢推定/AL))	134

●Additional Sources Not Captured by the Search Strategy

References［1］,［2］,［5］,［7］,［12］,［13］,［14］,［15］,［16］,［17］,［27］,［28］,［29］,［30］,［63］,［64］,［65］,［66］,［67］,［69］

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