CQ18 What are useful findings for estimating the age of individuals in postmortem images?

Grade of recommendation: C2

Bone and teeth are available to estimate subject age with any condition of a corpse. The development in children and young adults up to the age of about 25, and degenerative changes in adults are used. In general, the greater the age of a person (the corpse) the lower the confidence that may be imputed.

Explanation----------

Age estimation from soft tissue

In undamaged, unputrefied corpses, findings from soft tissue are commonly used in age estimates, including the height and weight of the body in infants and children, hair color, loss of skin elasticity, skin pigmentation, and the progress of arteriosclerosis in adults [1]. However, it may be impossible to obtain some of these findings from postmortem images. There is a study that the INTERPOL postmortem (PM) form (https://www.interpol.int/How-we-work/Forensics/Disaster-Victim-Identification-DVI) has been analyzed to investigate how postmortem CT can contribute to the disaster victim identification process as proposed by Interpol. It was reported that interpretation of the reconstructed images has shown that much of the postmortem information required for identification can be gathered from CT data, with the exception of color information and details of fine (small) structures [2]. This makes it possible to know the findings of age estimates from postmortem imaging.

Age estimation from hard tissue

Bone and teeth are available to estimate the age of subjects for any condition of corpses. The general development of children and young adults up to the age of about 25 and the degenerative changes in older adults are used. In general, the higher the age of a person the lower the confidence of an age estimate [1, 3].

Some studies that investigated the relationship between hard tissue changes and chronological age did not envision application of the results to age estimation. We must bear in mind that even commonly used methods may not be rigorously validated.

1) Age estimation of children and young adults

The appearance and fusion of ossification centers and the stage of fusion of some epiphyses are useful in findings of skeletal age up to about 25 years of age [1, 3]. The relationship between bone development and chronological age has long been studied using simple radiography in addition to

macroscopic observations, but there are still few studies using postmortem CT or MRI in this field [4-10].

Tooth formation and eruption are useful findings for dental ages up to about 25 years of age [1, 3]. Schour and Massler's chart [11] showing the development of human dentition is a well-known method for assessing the relationship between dental development and chronological age. Such charts, called dental age estimation charts, are commonly applied for age estimates. Validation studies of the accuracy of age estimates using these charts show that the accuracy is higher when using a chart made with data from a population close to that of a subject rather than using more general charts, such as Schour and Massler's chart [12, 13]. There is a Japanese dental development chart reported by the Japanese Society of Pedodontics [14]. Age estimation methods employing staging of dental development have also been reported. Recently, much research has been conducted on the Demirjian's method [15, 16], but it has been found that this method overestimates the age of subjects [8, 17], and the method was modified and is referred to as the Willems method [18]. Some systematic reviews and meta-analyses have shown that the Willems method of dental age estimation yields comparatively fewer overestimates, even though the accuracy is still not fully validated [19-22].

The recent increases in immigrant and refugee numbers has put the focus on methods to estimate the legal age that distinguishes minors from adults. The legal age for adults is 18 years in many countries, and many reports have shown the accuracy of methods to estimate whether a subject has reached the age of 18. A German-based research group called "The Study Group on Forensic Age Diagnostics (Arbeitsgemeinschaft für Forensische Altersdiagnostik: AGFAD)" currently recommends a method for assessing the bones of the hands and carpals, the proximal ends of the clavicle, and the third molars [23]. The various methods, such as the atlas methods proposed by Greulich and Pyle [24] or Tanner-Whithouse [25, 26] to assess the hands and carpal bones, Schmeling's method [27, 28] to assess the proximal clavicle, Cameriere's third molar index "I_{3M}" [29, 30] or the root formation stages of the third molar [31] to assess the maturity of third molars, are commonly used, and these methods have been evaluated in systematic reviews.

2) Age estimation of adults

The degenerative changes of bones and teeth with aging are useful in age estimations of adults [1, 3]. According to dry bone studies, the commonly used findings are as follows: cranial suture closure, pubic symphysis, the trabecular structure of the long bones (the humerus and femur) and the pubic bone, the articular surface degeneration of ribs and iliac bone, osteophytes, and tooth attrition, and other observations have also been used [3].

The relationship between the degenerative changes of bones and the chronological age has long been studied using simple radiography in addition to macroscopic observations. Age estimation

studies in adults using CT showed the following degenerative changes: closure of cranial sutures [32], increased length of the pubic bone in the coronal section and narrowing of the thickness of the connective tissue at the pubic symphysis [33], trabecular changes of the pubic and iliac bones [34], age-dependent morphological features of the coxal bone [35], and others.

A major research topic in age estimation using dental radiography is the decrease in the pulp/tooth ratio due to the increases in secondary dentin deposition of the pulp cavity with age [36, 37]: Kvaal's method calculates the pulp/tooth lengths and widths using periapical X-rays [38], Cameriere's method calculates the pulp/tooth area using periapical X-rays [39], and there are methods that determine the pulp/tooth volume using CT [40-44].

Column----------

Identification of specific persons refers to identifying who a whole or partial human body, stain, or other trace belongs to, or from whom it came. One of the advantages of images such as CT and X-ray images here is that they can be used whether individuals are dead or alive. Personal identification of the dead comprises two major aspects: reconstruction and comparison. Identification of a corpse is performed for legal, social, humanitarian, and police investigation reasons, among others [1, 45].

Reconstructive identification refers to determining or estimating the species (human or animal), sex, age, stature, and ancestry, and establishing specific broad groupings in investigations of potential victims [1, 45]. Methods used in anthropology and forensics are being applied to new studies using images. In addition, the characteristic findings of particular individuals, such as from implanted medical devices, are information that is simply identified and recorded on images and is useful in investigations of candidate identifications. Such characteristics and details can also be useful for comparative studies [1, 46].

Comparative identification is where the characteristics of an unknown person (postmortem data in case of a dead subject) are matched against the characteristics of a missing person (ante-mortem data in case of a dead subject) to determine whether they are from the same person and so makes it possible to make an identification [1, 45].

When the comparison is performed using images, the accuracy of a comparison can be improved by increasing the number of characteristics identified. Images are also important as an objective record that can be reused if re-examination is needed.

Literature search formula and literature selection (2019/2/14)

PubMed

#	Search formula	Number of documents
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))	139
2	(((meta-analysis) OR systematic review)) AND "age estimation"	21

Ichushi（Medical Journal）(2019/2/13)

#	Search formula	Number of documents
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))	94

From other than search formula

[1-4, 6, 11-16, 23-27, 38-42, 44]

References

[1] Saukko P et al: The establishment of identity of human remains. In: Knight's forensic pathology 4th ed, p95-132, Boca Raton, FL: CRC Press, 2016

[2] Sidler M et al: Use of multislice computed tomography in disaster victim identification: advantages and limitations. Forensic Sci Int 2007; 169: 118-128

[3] Seta S et al: Age estimation. In: Appraisal of skeletons. P 153-278, Reibunsha, 1990 (Japanese)

[4] Lee HJ et al: The ossification pattern in paediatric occipito-cervical spine: is it possible to estimate real age? Clin Radiol 2015; 70: 835-843 (Level 4b)

[5] Torimitsu S et al: Age estimation based on maturation of the medial clavicular epiphysis in a Japanese population using multidetector computed tomography. Leg Med 2019; 37: 28-32 (Level 4b)

[6] Nougarolis F et al: Bone age estimation based on multislice computed tomography study of the

scapula. Int J Legal Med 2017; 131: 547-558 (Level 4b)
[7] Ekizoglu O et al: Applicability of T1-weighted MRI in the assessment of forensic age based on the epiphyseal closure of the humeral head. Int J Legal Med 2019; 133: 241-248 (Level 4b)
[8] Santoro V: Applicability of Greulich and Pyle and Demirijan aging methods to a sample of Italian population. Forensic Sci Int 2012; 221: 153. e1-5 (Level 4b)
[9] Dahlberg PS et al: Agreement between chronological age and bone age based on the Greulich and Pyle atlas for age estimation: a systematic review. Report from the Norwegian Institute of Public Health No. 2017-21. Knowledge Centre for the Health Services at The Norwegian Institute of Public Health (NIPH): NIPH Systematic Review: Executive Summaries [Internet]: 2017 https: //www.ncbi. nlm.nih.gov/books/NBK482103/. (Level 4b)
[10] Serinelli S et al: Accuracy of three age determination X-ray methods on the left hand-wrist: a systematic review and meta-analysis. Leg Med 2011; 13: 120-133 (Level 1)
[11] Schour I et al: The development of the human dentition. J Am Dent Assoc 1941; 28: 1153-1160 (Level 6)
[12] AlQahtani SJ et al: Accuracy of dental age estimation charts: Schour and Massler, Ubelaker and the London Atlas. Am J Phys Anthropol 2014; 154: 70-78 (Level 4b)
[13] Baylis S et al: Precision and accuracy of commonly used dental age estimation charts for the New Zealand population. Forensic Sci Int 2017; 277: 223-228 (Level 4b)
[14] The Japanese Society of Pedodontics: The chronology of deciduous and permanent dentition in Japanese children. The Japanese Journal of Pediatric Dentistry 1988; 26: 1-18 (Level 4b) (Japanese)
[15] Demirjian A et al: A new system of dental age assessment. Hum Biol 1973; 45: 211-227 (Level 6)
[16] Demirjian A et al: New systems for dental maturity based on seven and four teeth. Ann Hum Biol 1976; 3: 411-421 (Level 6)
[17] Jayaraman J et al: The French-Canadian data set of Demirjian for dental age estimation: a systematic review and meta-analysis. J Forensic Leg Med 2013; 20: 373-381 (Level 1)
[18] Willems G et al: Dental age estimation in Belgian children Demirjian's revisited. J Forensic Sci 2001; 46: 893-895 (Level 4b)
[19] Esan TA et al: The Demirjian versus the Willems method for dental age estimation in different populations: a meta-analysis of published studies. PLoS One 2017; 12: e0186682 (Level 1)
[20] Mohd Yusof MYP et al: Performance of Willem's dental age estimation method in children: a systematic review and meta-analysis. Forensic Sci Int 2017; 280: 245.e1-245.e10 (Level 1)
[21] Wang J et al: Is Willems method universal for age estimation: a systematic review and meta-analysis. J Forensic Leg Med 2017; 52: 130-136 (Level 1)
[22] Sehrawat JS et al: Willems method of dental age estimation in children: a systematic review and

meta-analysis. J Forensic Leg Med 2017; 52: 122-129 (Level 1)
[23] Schmeling A et al: Forensic age estimation. Dtsch Arztebl Int 2016; 113: 44-50 (Level 6)
[24] Greulich WW et al: Radiographic atlas of skeletal development of the hand and wrist. Stanford University Press, California, 1959 (Level 6)
[25] Tanner JM et al: Assessment of skeletal maturity and prediction of adult height (TW2 method). Academic Press, New York, 1975 (Level 6)
[26] Tanner JM et al: Assessment of skeletal maturity and prediction of adult height (TW3 method). W. B. Saunders, London, 2001 (Level 6)
[27] Schmeling A et al: Studies on the time frame for ossification of the medial clavicular epiphyseal cartilage in conventional radiography. Int J Legal Med 2004; 118: 5-8 (Level 4b)
[28] Hermetet C et al: Forensic age estimation using computed tomography of the medial clavicular epiphysis: a systematic review. Int J Legal Med 2018; 132: 1415-1425 (Level 1)
[29] Cameriere R et al: The comparison between measurement of open apices of third molars and Demirjian stages to test chronological age of over 18 year olds in living subjects. Int J Legal Med 2008; 122: 493-497 (Level 4b)
[30] Santiago BM et al: Accuracy of the third molar maturity index in assessing the legal age of 18 years: a systematic review and meta-analysis. Int J Legal Med 2018; 132: 1167-1184 (Level 1)
[31] Haglund M et al: A systematic review and meta-analysis of the fully formed wisdom tooth as a radiological marker of adulthood. Int J Legal Med 2019; 133: 231-239 (Level 1)
[32] Chiba F et al: Age estimation by multidetector CT images of the sagittal suture. Int J Legal Med 2013; 127: 1005-1011 (Level 4b)
[33] Chiba F et al: Age estimation by quantitative features of pubic symphysis using multidetector computed tomography. Int J Legal Med 2014; 128: 667-673 (Level 4b)
[34] Villa C et al: Forensic age estimation based on the trabecular bone changes of the pelvic bone using post-mortem CT. Forensic Sci Int 2013; 233: 393-402 (Level 4b)
[35] Biwasaka H et al: A quantitative morphological analysis of three-dimensional CT coxal bone images of contemporary Japanese using homologous models for sex and age estimation. Leg Med 2019; 36: 1-8 (Level 4b)
[36] Marroquin TY et al: Age estimation in adults by dental imaging assessment systematic review. Forensic Sci Int 2017; 275: 203-211 (Level 1)
[37] Bjørk MB et al: CT and MR imaging used in age estimation: a systematic review. J Forensic Odontostomatol 2018; 1: 14-25 (Level 1)
[38] Kvaal SI et al: Age estimation of adults from dental radiographs. Forensic Sci Int 1995; 74: 175-185 (Level 4b)
[39] Cameriere R et al: Age estimation by pulp/tooth ratio in canines by periapical X‐rays. J Forensic Sci 2007; 52: 166-170 (Level 4b)

[40] Someda H et al: Age estimation based on three-dimensional measurement of mandibular central incisors in Japanese. Forensic Sci Int 2009; 185: 110-114 (Level 4b)

[41] Agematsu H et al: Three-dimensional observation of decrease in pulp cavity volume using micro-CT: age-related change. Bull Tokyo Dent Coll 2010; 51: 1-6 (Level 4b)

[42] Aboshi H et al: Age estimation using microfocus X-ray computed tomography of lower premolars. Forensic Sci Int 2010; 200: 35-40 (Level 4b)

[43] Sakuma A et al: Age estimation based on pulp cavity to tooth volume ratio using postmortem computed tomography images. J Forensic Sci 2013; 58: 1531-1535 (Level 4b)

[44] Sasaki T et al: Human age estimation from lower-canine pulp volume ratio based on Bayes' theorem with modern Japanese population as prior distribution. Anthropol Sci 2014; 122: 23-35 (Level 4b)

[45] Yamada Y: Personal identification. Takahashi M supervised; Forensic dental sciences: From basic knowledge to clinical disaster response, p86-91, Nagai Shoten, 2017 (Japanese)

[46] O'Donnell C et al: Contribution of postmortem multidetector CT scanning to identification of the deceased in a mass disaster: experience gained from the 2009 Victorian bushfires. Forensic Sci Int 2011; 205: 15-28 (Level 5)