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## Early human hand morphology: an estimation of fetal age

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### Summary

Fetal hand morphogenesis was studied between 6 and 14 weeks of gestation by scanning electron microscopy. Detailed observations of surface features allowed three individualized phases of hand development to be distinguished, related to the shape (6 to 10 weeks), to the appearance of creases (10 to 13 weeks) and of ridges (13 weeks onwards).

fetal age; human hand; dermatoglyphics; abortion material; scanning electron microscopy

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### Introduction

There have been numerous detailed studies of human limb development (for review see ref. 31); the earliest as far back as 1685 [2] and 1686 [19]. More recent studies centered on morphogenesis [3,25] as well as on myogenesis [7], osteogenesis [12] and development of joints [10,26,27]. The development of the upper limb during the embryonic period (8 postovulatory weeks) was carefully analyzed by O'Rahilly and Gardner [28]. Comparisons were made with that of other organs in order to define precise stages during this period of embryogenesis.

Investigations of the morphology and biochemistry of human embryonic organs require reference criteria for fetal age. This is especially true when human fetal material originates from deliberate termination of pregnancy or from certain therapeutic abortions. In the clinic, pregnancy is estimated from the first day of the last menstrual period and fetal age is consequently estimated by subtracting two weeks. This simple evaluation leads to unavoidable errors such as uncertainty about the day of fertilisation due to the variable length of the ovarian cycle, or to erroneous

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reporting by the woman herself, linked to her concern to place the fetal age within legal limits.

Estimation of fetal age is generally based on measurements of crown-rump (CRL) or crown-heel length (CHL) which have been compared by many authors [1,9,29,32-34]. Although these criteria have been used by all of them, the review of Gray and Skandalakis [14] reveals discrepancies between their evaluations of fetal age.

It is noteworthy that measurements of CRL or CHL can be impossible to perform in abortion material where undamaged fetuses are the exception. Nevertheless, the almost invariable presence of intact limbs provides a useful reference organ, especially because limb organogenesis occurs during the first trimester of pregnancy. Despite the fact that CRL or CHL measurements provide a good estimate of fetal age, the importance of additional criteria has already been recognized. Thus, Dylevsky [11] proposed the use of long limb bone measurements and their comparison with CRL. For all these reasons we have focused our study on the external organogenesis of the hand and in particular on the developmental pattern of palm configuration. Related to this, as suggested by Miller [22], the use of techniques designed for the preparation of specimens for scanning electron microscopy (SEM) and their observation is of considerable interest. Indeed, these experimental procedures, metallization in particular, emphasize both relief and contrasts.

The purpose of the present work is to propose a suitable method for rapid estimation of fetal age in weeks based on the progressive appearance of external hand surface features which have been correlated with significant data in the literature.

### Material and Methods

Human fetuses were obtained from therapeutic abortion, or termination for other reasons, following suction aspiration curettage, or hysterotomy, with the informed consent of the patients. Fetal age is roughly estimated before the examination of the hand, by weeks of amenorrhea. The intact fetuses analyzed as a basis for comparisons, originated either from hysterotomies or from the collection of the Laboratory

TABLE I  
Number of fetal hands analyzed between 6 and 14 weeks of gestation

Fetal age <sup>a</sup> (weeks)	6	7	8	9	10	11	12	13	14	16	17	18	19	20
No. of specimens <sup>b</sup>	5	5 (1)	7 (2)	10 (2)	4 (1)	5 (1)	4 (1)	2	2 (1)	1 (1)	1 (1)	1 (1)	2 (2)	1 (1)

<sup>a</sup> The fetal age indicated corresponds to that age obtained by examination of the hand.

<sup>b</sup> This is the same as the number of individual fetuses; in each case, the right or the left hand was examined. Numbers in parentheses represent the number of intact fetuses.

of Embryology (Medical School of Strasbourg). The total number of specimens is listed in Table I.

The hands were fixed in 10% formalin for direct observation under the dissecting microscope. For scanning electron microscopy (SEM) they were fixed in 2% glutaraldehyde buffered with 0.2 M cacodylate (pH 7.4) for 2 h at 4°C. They were then dehydrated, dried in a critical point drier (Balzers Union) and coated with gold



Fig. 1. Fetal development of the human hand between 6 and 14 weeks: SEM observations. a, b, c, d: 6, 7, 8, 9 weeks; magnification  $\times 40$ . e, f, g: 10, 11, 12 weeks; magnification  $\times 20$ . h, j: 13, 14 weeks; magnification  $\times 10$ . i: detail of ridges at 13 weeks; magnification  $\times 320$ . Abbreviations: T, radial position of the thumb anlage; UP, single underdigital pad; IP, interdigital pad; DP, digital pads; TC, thumb opposition crease; PC, proximal palmar flexion crease; DC, distal palmar flexion crease; TA, thenar pattern area; HA, hypothenar pattern area N, nail position.

using a sputter coater (Balzers Union). The preparations were examined with a Philips 501 B scanning electron microscope.

### Results and Discussion

Our observations on external hand morphogenesis are illustrated in Figs. 1 and 2. They are correlated in Table II with the CRL measurements of Patten [29] and with the main skeleton characteristics of O'Rahilly and Gardner [28].

The characteristics which will be discussed in order are the length of the hand, its shape, the palm configuration and the progressive appearance of pads, creases and ridges.

The first point concerns the length of the hand during the gestational period from 6 to 14 weeks. In spite of individual variations of this parameter (Table II), hand length grows in direct proportion to the CRL. This observation is based on a comparison of hand and crown-rump length in nine intact fetuses, reported in Table II. We have also compared the mean length of all hand specimens in the abortion material to the CRL values of Patten [29]. It is noteworthy that hand length corresponds to about 10% of the CRL. This result corroborates the value (ca. 9%)

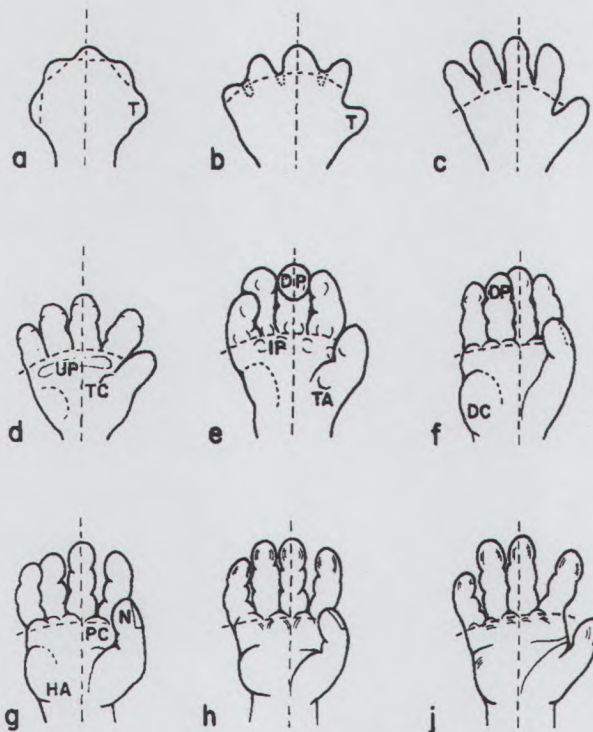


Fig. 2. Fetal development of the human hand between 6 and 14 weeks: schematic drawings. Fetal ages and abbreviations are the same as in Fig. 1.

reported by Dylevsky [11] and based on a sophisticated mathematical correlation between hand-bone length and CRL. A similar relationship has been observed for fetal foot length by Bossy and Katz [6]. The interesting suggestion about influences linked to the genetic sex of the fetus [13] could not be confirmed in this abortion material.

The external shape of the hand is entirely accomplished during the period from 6 to 10 weeks of gestation (Figs. 1 and 2). As early as 6 weeks (the earliest stage studied) an asymmetry of the hand primordium, defined by the slot of the thumb, appears, and represents the first organization of the hand (Figs. 1 and 2, a, b). An opposed position of the thumb constitutes a characteristic of the human hand and distinguishes it from the hand of primates [8,20,24]. The phenomenon of thumb opposition occurs progressively: at 8 weeks all the developing fingers are in the same spatial plane, whereas at 10 weeks thumb rotation is achieved (Figs. 1 and 2, c, d, e).

The configuration of digital and interdigital pads is acquired progressively: in a first phase of intense development extending from 9 to 10 weeks, the interdigital pads become very prominent (Figs. 1 and 2, d, e) whereas the same phenomenon occurs for the digital pads between 10 and 12 weeks (Figs. 1 and 2, f, g). In a second phase of development, both types of pads regress. Although this regression is a well known phenomenon, it is interesting to note that it starts much earlier than the 5 months proposed by Hirsch and Schweichel [17]. Indeed, interdigital pads begin to regress as early as 11 weeks and digital pads from 13 weeks onwards (Figs. 1 and 2, f, g, h). The present observations illustrate that complete development of pads precedes the appearance of the ridges, confirming the much older views of Bonnevie [4,5] and the more recent ones of Holt [18], Blechschmidt [3] and Mulvihill and Smith [23]. To validate our SEM observations on the configuration of pads, the following comments can be made. As far back as 1952, Hale [15] was able to show that the pads correspond to mesenchymal condensations on the surface of which the ridges appear. Several other authors using combined histological and ultrastructural studies confirmed the mesenchymal origin of the pads and their structural arrangement; they further suggested the role of blood vessel nerve pairs in their appearance [16,17,30].

The development of the creases is characterized at 10 weeks of gestation by opposition of the thumb which induces the first appearance of a crease demarcating the thenar pattern area (Figs. 1 and 2, e). It is followed by the appearance of the palmar distal and proximal creases, which become evident at 11 and 12 weeks, respectively (Figs. 1 and 2, f, g), the consequence of which being the delimitation of the hypothenar pattern area. The interphalangeal flexion creases are the latest to appear in a progressive manner from 11 weeks onwards (Figs. 1 and 2, f).

The ridges represent the first anlage of the fingerprints. In our study, the use of SEM shows that ridges are present as early as 13 weeks (Fig. 2, h). This precocious appearance has also been suggested by Hale [15], but is at variance with the five months stage proposed more recently by Hirsch and Schweichel [17]. The formation of ridges begins on the lateral part of the fingertips as seen with SEM and proceeds further from a lateral-distal to a medial-proximal position on the end phalanx. This description correlates very well with the histological pictures of Hale [15] and Hirsch

TABLE II  
Main characteristics of fetal hand development between 6 and 14 weeks of gestation

Fetal age (weeks)	Crown-rump length (mm) <sup>a</sup>	Hand length (mm) <sup>b</sup>	Characteristics of skeleton <sup>c</sup>	General shape of the hand <sup>d</sup>	Creases <sup>d</sup>	Ridges <sup>d</sup>
6	8-12	1 (0.9-1.3)	radius, ulna and metacarpus begin to chondrify	-hand primordium with prefiguration of finger slots, -radial asymmetry of the thumb	-	-
7	12-20	1.5 (1.1-1.7)	carpus and proximal phalanges begin to chondrify	-hollowing of the digital grooves, -separation of the thumb	-	-
8	21-30	2.4 (1.9-2.9)	middle and distal phalanges begin to chondrify	-appearance of individual fingers, -primordium of the second phalange	-	-
9	30-39	3.1 (2.7-4.0)	radius, ulna and metacarpus begin to ossify	single under-digital pad, -thumb rotation and thenar pattern area emergence	-	-