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Anatomy of the seated position: methodologic approach and initial findings

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Summary. The aim of this research was an anatomic study of the seated position in order to reply, in particular, to various questions raised in certain industrial situations as to this position and the reciprocal adaptation of the human being and his seat. The methodology adopted was based on obtaining reference serial sections from an entire subject frozen in the seated position, as well as on computerised three-dimensional reconstruction. The difficulty of the undertaking led us to specify this methodology, which must be strictly adhered to. Different types of visualisation were then considered, showing the feasibility of the method, which can effectively respond to the demands of industrial situations by allowing the creation of a data bank, and also by opening up new perspectives in the field of anatomical teaching.

Anatomie et position assise : approche méthodologique et premiers résultats

Résumé. Le but de ce travail est, à terme, l'étude anatomique de la position assise afin de répondre notamment, aux interrogations diverses posées dans certains milieux industriels sur cette position et sur l'adaptation réciproque de l'être humain et du siège. La méthodologie utilisée repose sur la réalisation de coupes sériées référencées d'un sujet entier congelé en position assise, ainsi que sur sa reconstruction tridimensionnelle par informatique. La difficulté de l'entreprise nous a conduits à préciser cette méthodologie qui doit être parfaitement rigoureuse. Différents types de visualisation sont alors envisagés montrant la faisabilité de la méthode, qui peut effectivement répondre aux besoins des milieux industriels en permettant la création d'une banque de données, mais aussi ouvrir des perspectives nouvelles dans le domaine de l'enseignement de l'anatomie.

Key words: Anatomy — Seated position — Anatomic sections — Three-dimensional reconstruction — Modelling — Data bank

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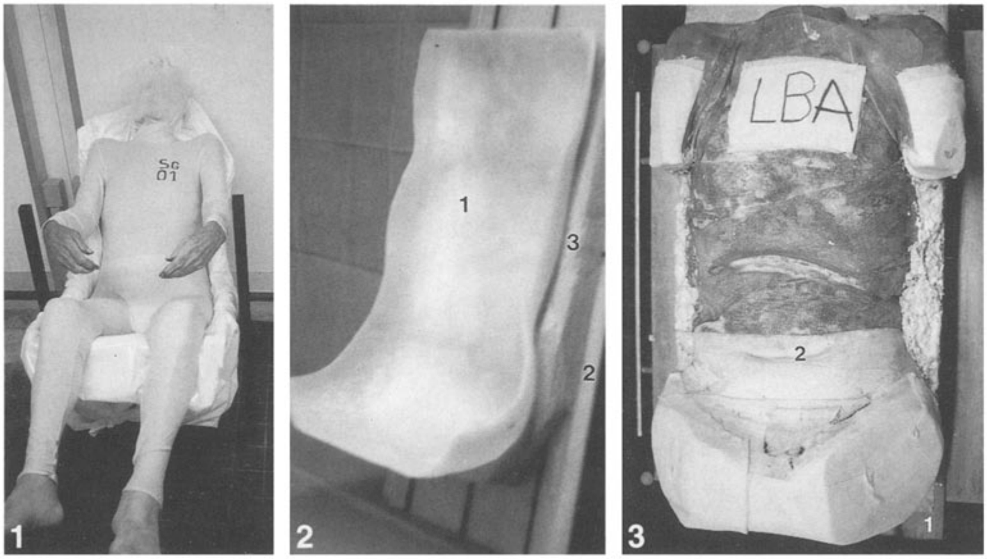
Anatomy, as the fundamental science of medical and paramedical studies, uses a reference position defined by an international convention: "the living human body, standing, the head vertical and facing forward, the gaze straight and horizontal, the upper limbs hanging by the side of the body, with the palms of the hands directed foward, the feet parallel and directed forward". This convention is due to the inherent needs of teaching.

If it is asked whether study of the seated position is of any importance, the reply must be in the affirmative. Some of the questions raised in terms of the fundamental anatomy, and of the medical consequences of the seated position, are as follows: How does the skeleton adapt to this position? What changes of orientation does this position impose on the articular and muscular planes, and with what consequences? How is the new equilibrium of the vertebral column established? What modifications are imposed on the neurovascular structures, particularly in the lower limbs? Is it possible to deduce the effects on the mechanics of the circulation? Is the topographic anatomy of the trunk modified compared with that in the standing position? If there are any modifications, what are they and what are the new landmarks?

Industry also requires precise anatomic concepts in order to understand the adaptation of subject and seat, to know the essential points



Figs. 1-3
1 Frozen subject in seated position in the shell of a bucket seat. **2** Shell/slab assembly. *1*, shell; *2*, reference slab; *3*, foam ensuring bonding between shell and slab. **3** Final assembly. *1*, reference slab; *2*, subject after different sections, covered with scotch-cast

1 Sujet en congélation en position assise dans la coque de siège baquet. **2** Assemblage coque-plaque. *1*, coque; *2*, plaque de référence; *3*, mousse assurant la liaison coque-plaque. **3** Assemblage final. *1*, plaque de référence; *2*, le sujet après les différentes sections, recouvert de scotch-cast

of support, to learn the effects oskeletal landmarks in relation to their cutaneous envelope, and to define the zones of possible compression. This study should help to define objective criteria of the concept of comfort in the seated position.

The users of means of transport usually travel in the seated position in private automobiles, road transport vehicles, railways and aircraft. Does the seated position of the traveller influence the severity of the lesons observed in cases of frontal, lateral or other impacts? Which are the most vulnerable points? Which zones should be protected? The characteristics of the seat and those of its support system, when one is used, favor a particular seated position; is there, in case of accident, one position more favorable than another, and if so, how is it to be defined? It is known that an uncomfortable, and therefore tiring, sitting position may cause an accident.

The designers of seats and, more generally, of workplaces, must have precise data on the seated position. Yet there is not at present any anatomic data bank on the seated position that would permit of mechanical models or precise computation. Hence the importance of this study, performed to a great extent at the request of industrialists. If one wishes to design a serious study of ths seated position for the creation of a data bank, the most suitable methodology is not by dissection, or conventional radiography, not even by computed tomography or MRI (a human being cannot at present undergo such investigations in the seated position). It seemed that the combination of a conventional technique of classical anatomy, the performance of serial sections and their three-dimensional reconstruction, would allow a useful approach to this question. We shall discuss the principles and the initial findings by showing some of the images obtained and their importance. Certainly, there can be no question, after this first and necessarily limited experience, of arriving at any conclusions on the seated position(s).

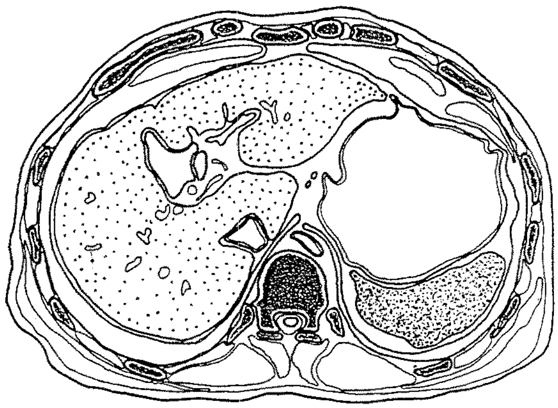
Methodology

Preparation of the subject and performance of anatomic sections

The subject chosen was male, aged 71 years, 168 cm in height and 64 kg in weight, i.e. fairly close to the 50th percentile by analogy with experimental dummies. It was preserved by Winckler's method [4]. The interest of the laboratory in road safety led to the choice, among the different seated positions, of that given by the shell of a seat without its foam coverings. After recording the different parameters of positioning, the subject was frozen at -23°C (Fig. 1).

The objective of three-dimensional reconstruction required the performance of planes of section that were equidistant and parallel, and that the anatomic sections should be perfectly referenced and not in the smallest degree deformed before photography and analysis. After molding in plaster, a shall of polypropylene 10 mm thick was constructed, enveloping the posterior and lateral parts of the trunk, the shoulders and buttocks. This shell was fixed on a squared reference slab of polypropylene 19 mm thick, 1000 mm long and 450 mm wide. This sheet was grooved (three grooves parallel to the long axis and one parallel to the transverse axis). The neck was divided at the level of C5-6, the arms at the middle third and the thighs at the junction of the upper and middle thirds so as to allow subsequent computed tomography.

The shell was fixed to the reference slab by means of a foam with two



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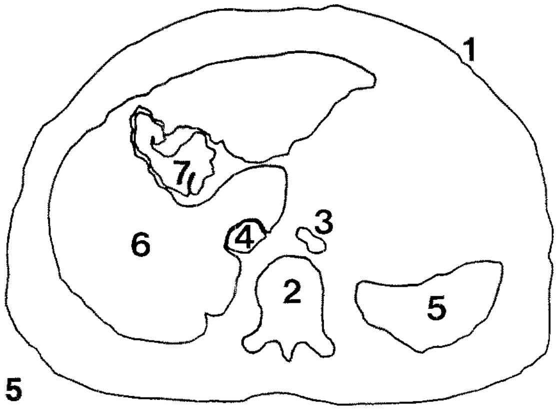

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Figs. 4, 5
4 Diagram of section at T10. *+1*, reference points. **5** Diagram simplified for numerisation. *1*, skin; *2*, vertebral column; *3*, abdominal aorta; *4*, inferior v. cava; *5*, spleen; *6*, liver; *7*, gallbladder

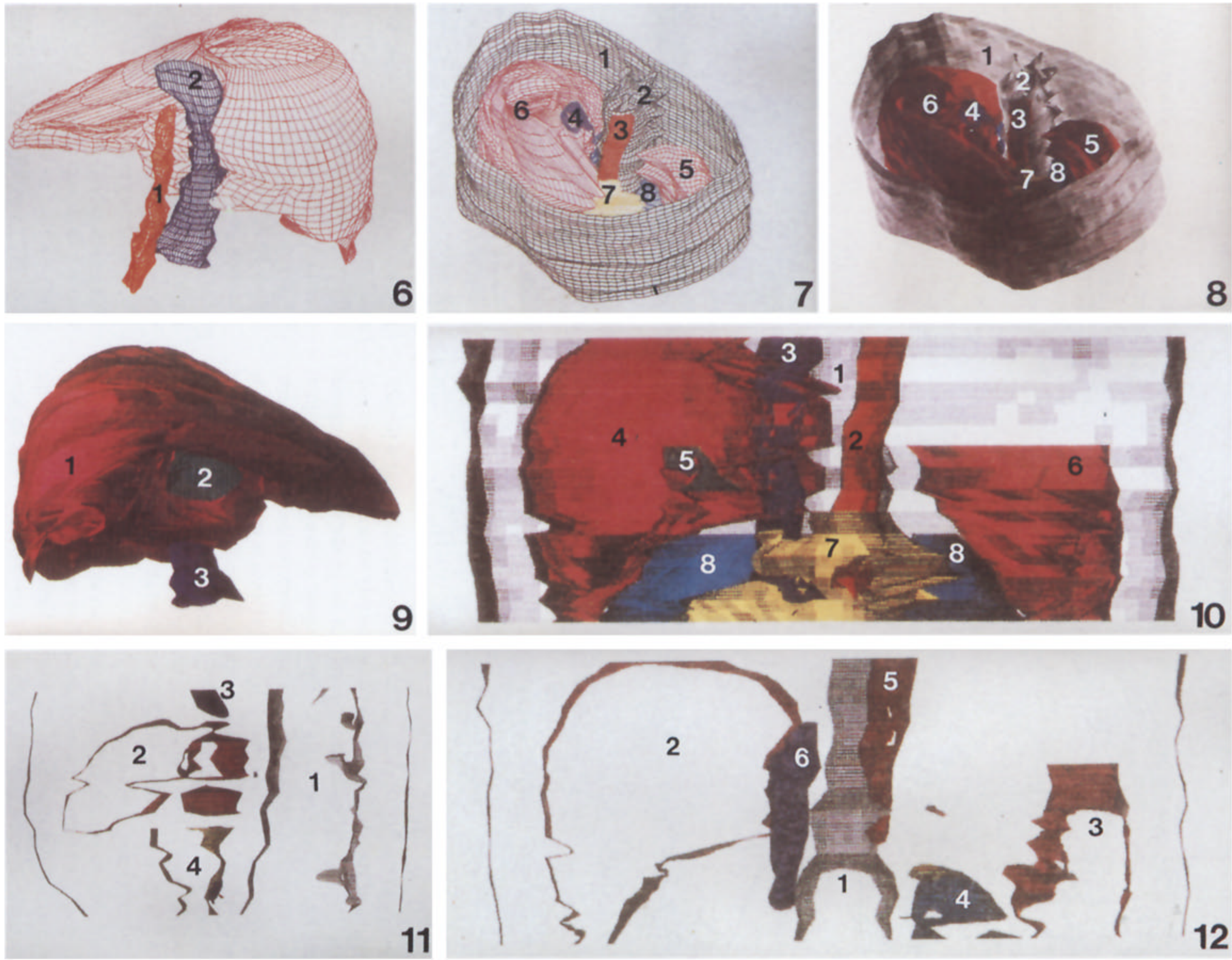
4 Schéma de la coupe en T10. En *+1*, les points de référence. **5** Schéma simplifié pour numérisation. *1*, peau; *2*, colonne vertébrale; *3*, aorte abdominale; *4*, v. cave inférieure; *5*, rate; *6*, foie; *7*, vésicule biliaire

components of high rigidity (Fig. 2). The positioning of the shell on the reference slab was done under an image intensifier, so as to perfectly center the subject in relation to landmarks and to avoid any possible rotation of the vertebral column. The last stage of preparation of the block for sawing was designed to immobilise the preserved bodily structures in relation to the reference slab until photography of the sections obtained. The anterior portion of the subject was totally covered with strips of resin polymerisable in water (scotchcast) and the conjunction between shell and slab was immersed in a block of monoconstitutent foam including the ends of the scotch-cast strips (Fig. 3). The entire block was subjected to computed tomography so as to obtain serial sections every 10 mm (the sweep thickness was 5 mm). The location previously made on the reference slab made it possible subsequently to achieve correspondence of the anatomic and computed tomographic sections with the aim of mutual interpretation and correlation. The anatomic sections were made using a ribbon saw with a power of 7.5 Ch and a speed of 600 rotations a minute, with a fine-toothed blade (2.5 teeth/cm). Stability of movement of the blade was ensured by two guides situated immediately above and below the block for section. In order to facilitate manipulation of the anatomic specimen, this was sectioned into half-blocks following the transverse groove of the reference slab. During sawing, the half-block or, more precisely, the reference half-slab carrying the specimen for sawing, glided over the saw-face, lubricated by sprayed silicone, between two guide structures perfectly parallel and integral with the saw-face. This ensured rectilinear displacement of the anatomic specimen. The planes of section were spaced at 10 mm intervals; as the saw-blade caused loss of 2 mm of substance, the sections were 8 mm thick.

Each section was immediately placed and stuck to a numbered slab of polypropylene and returned to refrigeration at -23°C. 66 sections were made between the level of C5-6 and the interface of buttocks and shell. These sections were then cleaned by scraping and with compressed air; in order to prevent any deterioration due to possible thawing, the sections were not exposed for more than 15 min to the ambient air. The sections were covered with cellophane to prevent any dehydration.

Preparation of the working document and data capture

All the sections were photographed along an axis perpendicular to their plane, with constant enlargement. The section was placed on a negatoscope so as to eliminate shadows produced by the hollow organs; the superior lighting was obtained from a fixed light and two spotlights, each of 400 W; the apparatus was an Olympus OM2, 24 x 36, equipped with a 50 mm macro objective, with a section-objective distance of 500 mm. The photographs were made on reversible color film, with a sensitivity of 50 ASA for artificial light. The diapositives were projected on a translucent table; each section was then outlined on reference tracing paper 420 x 297 mm (Fig. 4) on which were carefully noted two reference points corresponding to two of the longitudinal grooves of the slab. From these first anatomic outlines there were obtained simplified diagrams using the data-acquisition phase. It is, in fact, essential to simplify the original diagram by selecting the organs to be captured and smoothing to some extent the shapes



Figs. 6-12
6 Dorsal view of liver (*hidden lines* suppressed). The viewpoint is raised 15° in relation to the horizontal plane. *1*, abdominal aorta; *2*, inferior v, cava. **7** Latticing made from 14 sections of thoraco-abdominal level, 3/4 left-forward view, viewpoint raised 45° in relation to horizontal plane. *1*, skin; *2*, vertebral column; *3*, abdominal aorta; *4*, inferior v. cava; *5*, spleen; *6*, liver; *7*, pancreas; *8*, kidney. **8** Shaded version of Fig. 7, same legend. **9** Ventral view of liver with downward tilt of 30° from viewpoint. *1*, liver; *2*, gallbladder; *3*, inferior v. cava. **10** Frontal section with preservation of posterior structures. *1*, vertebral column; *2*, abdominal aorta; *3*, inferior v. cava; *4*, liver; *5*, gallbladder; *6*, spleen; *7*, pancreas; *8*, kidney. **11** Right paramedian sagittal section. *1*, vertebral column; *2*, liver; *3*, inferior v. cava; *4*, pancreas. **12** Frontal section passing through anterior part of vertebral column. *1*, vertebral column; *2*, liver; *3*, spleen; *4*, kidney; *5*, abdominal aorta; *6*, inferior v. cava

6 Vue dorsale du foie (lignes cachées supprimées). Le point de vue est élevé de 15° par rapport au plan horizontal. *1*, aorte abdominale; *2*, v. cave inférieure. **7** Maillage réalisé sur 14 coupes de l'étage thoraco-abdominal. Vue de 3/4 avant gauche, point de vue élevé de 45° par rapport au plan horizontal. *1*, peau; *2*, colonne vertébrale; *3*, aorte abdominale; *4*, v. cave inférieure; *5*, rate; *6*, foie; *7*, pancréas; *8*, rein. **8** Ombrage de la Fig. 7; même légende. **9** Vue ventrale du foie avec bascule du point de vue de 30° vers le bas. *1*, foie; *2*, vésicule biliaire; *3*, v. cave inférieure. **10** Coupe frontale avec conservation des éléments postérieurs. *1*, colonne vertébrale; *2*, aorte abdominale; *3*, v. cave inférieure; 4, foie; *5*, vésicule biliaire; *6*, rate; *7*, pancréas; *8*, rein. **11** Coupe sagittale paramédiane droite. *1*, colonne vertébrale; *2*, foie; *3*, v. cave inférieure; *4*, pancréas. **12** Coupe frontale passant par la partie antérieure de la colonne vertébrale. *1*, colonne vertébrale; *2*, foie; *3*, rate; *4*, rein; *5*, aorte abdominale; *6*, v. cave inférieure of the anatomic structures so as not to create data-phases of numerisation that are too complex and too large.

The computer equipment consisted to two Hewlett Packard microcomputers (Vectra RS/25C), two digitising tablets, a tracer and a color printer; we used CAD software (Autocad V10), supplemented by software for the modelling of images (Autoshade V1.1).

The acquisition procedure was made plane by plane: preliminary capture of the two points belonging to the reference coordinates of the subject and keyboard entry of the coordinates (x,y) of these points measured on the reference slab; manual numerisation of the envelopes of the different organs visible on the section in the form of 3D polylines; definition of the coordinate z in terms of the "altitude" of the section considered (the elevation step corresponded to the interval between two sections, i.e. 10 mm). Each of the sections required the acquisition of at least 2000 points.

Initial findings: different types of visualisation

The data-bases created made it possible to obtain computerised diagrams of each horizontal section (2-D versions), useful both for the teaching of anatomy and for the relevant industrial situations . These diagrams may, according to need, be presented in complete or simplified form, improved by changes of orientation, superimposed, etc.

Computerised treatment by latticing provides spatial visualisation of the "wire line" type of an organ, a group of organs (Fig. 6) or a body level (Fig. 7). A complementary treatment, by shading of the "wire line" views (Fig. 8) leads to improved realism. Here again, different views of one or more anatomic structures are possible (Fig. 9). It is also possible to obtain views "from within" of the 3-D reconstructions (Fig. 10) and reconstructions of sagittal sections (Fig. 11), frontal sections (Fig. 12) or even oblique sections. Because of the time required for data acquisition, only the thoraco-abdominal level and the pelvis have been reconstructed so far.

Discussion

The first question that must be raised is that of the feasibility of the method. The initial findings (it has not yet been possible to analyse all the data of this first study) show that this question can be answered affirmatively. The method is certainly tedious, but concrete and realistic. It is akin to 3-D reconstruction in MRI, but more precise. Unlike MRI, it can be applied to the seated subject.

The making of serial sections with a view to 3-D reconstruction has its imperatives. Our technique has given excellent results; we have obtained sections that were perfectly parallel, referenced and undeformed. We hope to be able to improve this technique in its application, while preserving its reliability.

As we have found, once the sections are made their transfer to the computer makes consultation with an anatomist essential, since an anatomic drawing must be made from each section and interpreted. The simplifications possibly required to improve the quality of the computer treatments must also be checked by the anatomist.

The document provided by the anatomist can then become the object of semi-automatic data capture, on which we are working, in order to set up the data banks. The treatment of these data-banks requires more effective computer methods than those currently available to us, and possibly the creation of an appropriate software.

The results we have obtained (a single subject, incompletely analysed) do not allow us to answer the different questions we set ourselves about the seated position. Certainly, it is indicated to complete the study of this first subject and to work with other subjects of different sex and size. However, our technique seems worthy of interest and reliable, and should be able to provide a study, both qualitative and quantitative, of the seated position(s).

Conclusion

This research on the seated position was initiated following questions raised by certain specialists in traffic safety, ergonomics and industry. The technique we have employed must comply with the questions raised by establishing a uniform bank of anatomic data on the seated position. Because it is visual and spatial, this same technique can provide the student with a new and very useful approach, and it can also furnish data and documentation of a quite irreplaceable nature to the authors of anatomic studies and the designers of software for human modelling.

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