ABSTRACT

Project goal is development of a technique for accurate measurement of a native head position in 3D coordinate system, i.e. difference determination between anatomical coordinate system and physical coordinate system. In other words determination of aberration of anatomical horizontal, vertical and transversal plane from physical planes in degrees.

A native hold of the head is changeable but it is held in close limits by healthy man. Big abnormalities are depended on a body position (stand vs. lie), but in case of stand approximately correspond with physical space. Accurate measurement of a native hold of the head is difficult and has not been pursued until now. Measurement of bigger abnormalities in case of pathological states is pursued either qualitatively by measuring of an abnormality from lead or by similar approximative methods or by sophisticated methods like search coil technique [1] or by scanning sensors fixed on the head. These techniques have a lot of disadvantages – they require special plant, restrict an extent of movement of a patient or affect a position of a head by fixing sensors.

KEY WORDS

Noninvasive Measurement, Head Position, Neurology

1. Introduction

There are a lot of abnormalities coming in many pathological states. The most frequent are blockages and disorders of a position of a cervical spine when abnormalities of hold of a head in a big extent often come. In case of movement disorders of the group of dystonias an abnormality of setup of affected body segments is typical. Abnormalities of hold of a head position known as torticollis, are the most frequent dystonias at all (see. Fig. 1). Position of a head in these cases correspond with activation of affected muscles and is typical for them (side tilt, forward tilt, backward tilt, circumvolution of a head).

Ophtalmogyric pareses cause a typical compensation setup of a head when the patient eliminate insufficient function by tilt in the direction of an affected muscle (for example: backward tilt of a head with disability of the eyelid lifter) and then abnormality of a head position is diagnostic.

Disorders of vestibular system i.e. vestibular dystonia, caused by affect of a peripheral part of the labyrinth and central vestibular nuclei and ways, in typical cases caused during an acute phase above all disbalance of vestibuloocular reflex (nystagmus) and vestibulospinal reaction (disorder of preservation of an erect stand).

Among typical symptoms which outlives for a long time but are acute too count a compensative side tilt of a head which is perceptible during examination with a lead. Accurate measurement of a head position should be in these cases an important contribution to objectification and quantification of these disorders, mainly due to detection of a head position in care the abnormality is small and clinically virtually undetectable. In array of cases are abnormalities of hold of a head position just suggested and it is difficult to detect them by human eye. In clinical practice it is possible to evaluate just broad abnormalities which are already visible during clinical examination. From theoretical viewpoint it is necessary to highlight that extent of values for healthy people is not known. Much less disorders of a head position during healing and possible dynamics of these changes and impact of hold of
a head in case of light forms of these disorders are known. These pieces of knowledge have potential signification particularly in diagnostic of ophthalmogryic and vestibular disorders.

The technique of measurement of native hold of a head has not been developed for the use in clinical practice yet. The solution of this problem should fulfill these conditions:
A noninvasive, distance measurement without necessity of connection with a patient on measurement plant and attaching sensors. The technique must not impact a native hold of a head position. Accuracy of measurement should be 1-2 degrees. Execution should be quick including postanalysis. Determination of an abnormality of hold of a head position in degrees on axes x,y,z. A suitable graphic representation. Archiving of evaluated data in a database with possibility to compare data in timerow.

All these conditions are satisfied if data are evaluated from digital photography. There should be designated points on the head which represent anatomical coordinates and difference should be evaluated from the picture.

The problem is variability of external attribute on the skull which makes accurate determination of horizontal, vertical and transversal plane impossible so that they are the same for all people. A connecting line of orbital floor and ear canal is treated as the most accurate anatomical horizontal. For transversal plane it is possible to choose a connecting line between ear canals over vertex. These points are not usually in accurate planes of axes x,y,z, but their identification is easy and unchangeable for an individual person. Interindividual differences of position of these points are unquestionably a major source of variability for our suggested way of measuring the hold of the head in the space.

2. Methods

The solution of the problem has three parts: determination of anatomical horizontal difference, determination of vertical difference, determination of circumvolution extent.

2.1 Measurement of side tilt

We suppose that anatomical horizontal is defined by two points. In case the patient does not suffer from an eye disorder which affects eye position, it is possible to assign these two points as centers of pupils. In case we evaluate side tilt of patient with affected position of eyes(eye), it is necessary these points to be palpated as the lowest points on the patient’s orbital floors. A connecting line of orbital floor and ear canal is treated as the most accurate anatomical horizontal. So we suppose that a connecting line of both orbital floors defines the same horizontal.

As we find coordinates of these points, we are able to determine a direction vector \( u \) of line which is defined by these points. Physical horizontal is defined by setup of the camera with tripod and bubble glass. Vector of physical horizontal \( v \) in the picture is \( v = (1,0) \). Total angle of side tilt \( \phi \) is then calculated such as Eqn.(1).

\[
\phi = \arccos \left( \frac{u \cdot v}{|v|} \right), 0 \leq \phi \leq \pi, [rad]
\]  

(1)

It is possible to determine coordinates defined by centers of pupils or by distal borders of orbital floors by automatic image filtering (see Fig. 2). We used Image Processing Toolbox of Matlab [2] functions to find and highlight the centers of pupils by white color.

Fig. 2. Filtration – centers of pupils are highlighted by white color

2.2 Measurement of forward/backward tilt

A procedure of measurement is coincident with the procedure from paragraph 2.1. The points which define the anatomical horizontal are designated on the connecting line of ear canal and the distal border of orbital floor. These points define the vector \( u \) in Eqn.(1), see Fig. 3.

Filtering was used to find the coordinates of pasted marks.

Fig. 3. Filtering – finding and highlighting the marks.
2.3 Measurement of circumvolution extent

• Description of geometry:
Measurement of circumvolution extent is the most difficult part of this solution. For determination of the circumvolution extent we use two pictures – from the left and from the right in which we detect the coordinate of ear canal. In both situations the camera must be placed accurate on the same axis which is parallel with frontal plane of a patient. Geometry of measurement is in Fig. 4.

Let the difference of coordinates of ear canals converted to millimeters \( x = (a - (s - b)) \times c \) [mm] and let the distance of ear canals (diameter of the head) \( d \) [mm]. Then total angle \( \varphi_c \) [rad] of circumvolution extent is calculated such as Eqn.(2).

\[
\varphi_c = \arcsin \left( \frac{a - (s - b)}{d} \right) \times c, \quad \frac{\pi}{2} \leq \varphi_c \leq \frac{\pi}{2}, \text{[rad]}
\]

(2)

where \( a \) [pixel] is x-axis value of coordinate of ear canal in the picture from the left, \( b \) [pixel] is x-axis value of coordinate of ear canal in the picture from the right, \( s \) [pixel] is x-axis size of the picture in pixels and \( c \) [mm] is constant which convert value of \( x \) from pixels to millimeters calculated such as Eqn.(3).

\[
c = \frac{ccd \cdot z}{fs} \text{[mm/pixel]},
\]

(3)

where \( ccd \) [mm] is the width of CCD sensor which is calculated from the sensor area which is presented by manufacturer, \( z \) [mm] is distance between CCD sensor and designated points, \( f \) [mm] is the focal length and \( s \) [mm] is x-axis size of the picture. [3]

• Procedure of measurement:
We designate an axis on the floor for example with an adhesive tape. We place tripods on this axis in the defined distance (we recommend 1m) and we designate the center between tripods. We set up devices on tripods horizontal and vertical by bubble glass. Turn on the laser beam and adjust the height of tripods at the same level. We move the head of the tripods around vertical axis simultaneously on both sides to achieve a detection of laser beams. If detectors detect the beams we fix the position of the heads of tripods. Turn off laser beam and place a patient on the mark in the center.

If we have two cameras with synchronous trigger, we take pictures. If we have only one camera we must take several pictures from both sides and calculate the average values of coordinates to eliminate the error of measurement which is generated by unconscious movement of a standing patient. In Fig. 6, you can see realization with a model.
3. Experimental results

We verified the methods shown above by experiments with models. On a styrofoam model of a human head we defined axis through a laser beam representing connecting line between ear canals. We fixed the model of a head into the machine with stepping motor and we adjusted the angle of circumvolution extent by 1.5 degree steps. Rotation cause a change of the constant $c$ in Eqn.(2) and Eqn.(3), trend of changes of this constant we determined empiric and we approximated it by linear function.

Results of measurement on the model for side tilt are presented in Tab. 1, where $\phi_s[^\circ]$ is angle of tilt of the model, $\phi_m[^\circ]$ is measured value and $|\Delta \phi[^\circ]|$ is the absolute error of measurement.

| $\phi_s[^\circ]$ | $\phi_m[^\circ]$ | $|\Delta \phi[^\circ]|$ |
|-----------------|-----------------|-----------------|
| 1.5             | 1.3             | 0.2             |
| 3.0             | 3.0             | 0.0             |
| 4.5             | 4.7             | 0.2             |
| 6.0             | 6.1             | 0.1             |
| 9.0             | 9.0             | 0.0             |
| 12.0            | 12.2            | 0.2             |
| 15.0            | 15.3            | 0.3             |

Tab. 1. Measured values for side tilt.

Results of measurement on the model for forward/backward tilt are presented in Tab. 2, where $\phi_s[^\circ]$ is angle of tilt of the model, $\phi_m[^\circ]$ is measured value and $|\Delta \phi[^\circ]|$ is the absolute error of measurement.

| $\phi_s[^\circ]$ | $\phi_m[^\circ]$ | $|\Delta \phi[^\circ]|$ |
|-----------------|-----------------|-----------------|
| 1.5             | 1.9             | 0.4             |
| 3.0             | 3.3             | 0.3             |
| 4.5             | 4.2             | 0.3             |
| 6.0             | 5.9             | 0.1             |
| 9.0             | 9.1             | 0.1             |
| 12.0            | 12.0            | 0.0             |
| 15.0            | 14.5            | 0.5             |

Tab. 2. Measured values for forward/backward tilt.

Results of measurement on the model for circumvolution extent are presented in Tab. 3, where $\phi_s[^\circ]$ is angle of circumvolution of the model, $\phi_m[^\circ]$ is measured value without any correction, $\phi_c[^\circ]$ is measured value after correction by correct. func. $f_i$ and $|\Delta \phi[^\circ]|$ is the abs. error of measurement. Correction function $f_i=0.84*\phi_m+0.05$.

| $\phi_s[^\circ]$ | $\phi_m[^\circ]$ | $\phi_c[^\circ]$ | $|\Delta \phi[^\circ]|$ |
|-----------------|-----------------|-----------------|-----------------|
| 1.5             | 1.2             | 1.3             | 0.2             |
| 3.0             | 3.4             | 2.6             | 0.4             |
| 6.0             | 7.3             | 5.6             | 0.4             |
| 9.0             | 10.4            | 8.4             | 0.6             |
| 12.0            | 14.2            | 11.5            | 0.5             |
| 15.0            | 17.7            | 14.3            | 0.7             |

Tab. 3. Measured values for circumvolution extent.

4. Discussion

In case of determination of side tilts we achieved very accurate results with a model. Of course the accuracy of measurement is dependent on how accurately anatomical coordinates are defined. In case of determination of circumvolution extent we achieved better than required accuracy too. Determination of correction function $f_i$ in dependence on diameter of a head, is still subject of research. For the present we determine this function empiric and use it in independent measurements. The question how to determinate an anatomical coordinate system is open too.

5. Conclusions

All the time we tried to find a simple flexible solution with minimal initial costs to this method will be accessible and user friendly. This technique complemented by database application which is able not only to evaluated data automatically but could classify them too, for example by sophisticated methods such as machine learning and data mining will be powerful and easy to use. This combination could bring new interesting findings in neurological practice.

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7. References

