Radiographic stereoplotting

A new technique and its application to the study of the spine

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Jacoby, R. K., Sims-Williams, H., Jayson, M. I. V., and Baddley, H. (1976). *Annals of the Rheumatic Diseases*, 35, 168–170. Radiographic stereoplotting. A new technique and its application to the study of the spine. Radiographic stereoplotting is a method for taking three-dimensional measurements from a pair of x-ray films. The x-ray technique is described, as is the stereoplotter. Using this machine it is possible to locate any point within the patient and measure the distance between that point and any other point. From this information it is possible to compute areas, volumes, and angles with great accuracy, which hitherto has been impossible using noninvasive techniques. It is planned to take measurements of the spinal canal in normal backs and in patients with nonspecific back pain, in order to try to define some of these syndromes on a structural basis.

It is likely that stereoplotting has some useful application in most branches of clinical medicine, since the x-ray technology is available in any diagnostic x-ray department.

Stereoscopic vision is a blend of two similar but nonidentical images on the retina of each eye. The images are merged by the brain to give three-dimensional perception. Stereoscopic radiography has been used as a diagnostic technique for about 40 years. Stereoplotting is a recent extension of this method, which allows accurate measurement of distances and angles within a three-dimensional structure. It is also possible to compute areas and volumes in three dimensions from paired radiographs.

Zeiss stereoscopic x-ray plotter (Fig. 1)

The apparatus has been developed from machines for photogrammetry, which is a technique used by land surveyors to plot map contours and to build three-dimensional models from aerial photographs. The resolution of these machines is such that objects only 6 inches in height can be plotted from photographs taken at 6096 m (20000 feet) and this technique has been used to plot the contours of the moon from satellite pictures. The x-ray plotter will allow measurement to be made to an accuracy of 0.1 mm.

Two observers can examine the radiographs simultaneously. The paired radiographs are carefully positioned

on two illuminated photocarriers mounted separately on a single carriage to give a three-dimensional image viewed through binoculars. The machine has two illuminated markers (m), one for each x-ray. These are focused onto identical spots so that they are seen as one mark through the stereoscope. The mark is fixed and defines a point in space. By altering the position of the photocarriers the x-ray films are moved relative to the mark and a point within the patient can be located on that mark in space. The position of the mark is defined by three axes, x, y, and z. The x and y axes are obtained by moving the carriage bearing both photocarriers from side to side (x axis) and forwards and backwards (y axis). The z, or vertical, axis is obtained by moving both photocarriers closer together or further apart so simulating a parallax effect and any plane in the x-ray appears to move in front of or behind the fixed mark.

The machine can only be switched on with the photocarriers in position such that all the axes are at zero, and all measurements are made with reference to that point. The co-ordinates locate the point in space under the illuminated mark along each axis with reference to zero. If the co-ordinates of two points in space are determined, then their distance apart can be calculated. The data from which the co-ordinates are derived is presented on an electronic screen and automatically programmed and fed

FIG. 1 X-ray stereoplotter with electronic cabinet and desk top calculator. Broad white beams represent the light path taken from the x-rays via the mirrors and binoculars to the eyes. The narrow white beams 'm' represent the illuminated marker

into a desk top calculator (Hewlett Packard 9810). The calculation of the distance between two points is automatically made. With data from three points it is similarly possible to calculate the area of the triangle they enclose. This can be applied to measurement of the areas of irregular or curved surfaces by dividing them into a series of small triangles and summing their areas. Similarly, the angle between three points, the solid angle between four points, and the volumes of solid structures are determined.

X-ray techniques (Fig. 2)

The paired radiographs can be obtained with any conventional x-ray unit. It is essential that the patient's position, the x-ray cassette position, and the film-focus distance are kept absolutely constant for the two exposures. Between exposures the x-ray tube is shifted a known distance along an appropriate axis (b) of the structure under investigation. As it is essential to align the films absolutely accurately on the photocarriers, radio-opaque index lines are fixed onto the x-ray film cassette, mounted on a sheet of perspex.

In examining the lumbar spine, the dose of radiation for a stereoscopic pair of anteroposterior radiographs is less than that required for the usual anteroposterior and lateral films, since the lateral view must penetrate a greater depth of tissue and requires a higher kilo voltage.

FIG. 2 Diagram of x-ray technique. The two exposures are represented by x-ray tubes 1 and 2. The x-ray source is moved along axis 'b', between each exposure. The patient remains in an identical position between each exposure and the second x-ray film is held in exactly the same position as the first

Computation of co-ordinates

The calculation of any measurement from the co-ordinate values is performed by the calculator which has a separate program for each type of measurement. The following

four values are required and incorporated into each program. (1) The film to x-ray focus distance (e). (2) The x-ray tube shift between each exposure (b). (3) The distance between the perspex mounted index lines and the x-ray film (a). (4) The optical constant of the stereoscope.

Preliminary results

(1) TO EXAMINE THE ACCURACY OF STEREOSCOPIC MEASUREMENTS

Stereoradiographs were taken of a dry articulated spine. Stereoscopic measurements were compared with real measurements of the dry spine in three axes, using a pair of precision callipers. The results obtained by both methods agreed to within 1% error. The greatest difficulty was in placing the callipers on exactly equivalent points to those used in the stereoscopic method and this probably accounted for much of the error.

Example: The maximum width of the sacrum

1. Stereoscopic measurement = 100.1 mm.
2. Calliper measurement of dried specimen = 99.1 mm.
3. Distance on x-ray film using a ruler = 114 mm.

Comment: Measurement 3 shows the inaccuracy of measurements taken straight from the x-ray films. This is because the x-ray beam is diverging and will give larger than true values, making even simple measurements inaccurate.

(2) TO MEASURE THE MOVEMENT OF THE VERTEBRAL BODIES ON FLEXION OF THE SPINE

Lateral stereoradiographs were taken of a 32-year-old man with lumbosacral low back pain, in flexion and extension. Clinical examination showed slightly diminished movement of the lower lumbar spine on flexion and extension, but not on lateral flexion. Measurements were made of the vertical distance between the anterior margins of the vertebral bodies L1 to L5.

Stereoscopic measurement:

	Flexion (mm)	Extension (mm)
L1/2	9.3	10.0
L2/3	9.3	10.9
L3/4	9.0	9.1
L4/5	9.6	10.8

Comment: The maximum movement at any one segment did not exceed 1.6 mm; however, at L3/4 there was very little movement observed. There were no osteophytes present in this patient so the abnormality was relative hypomobility in one segment. Although this could be seen on standard flexion and extension views and measured on the film, the stereoscopic measurements were made in three planes, thereby avoiding any discrepancy that might be caused by slight rotation of the spine.

Application to spinal disease

Radiographic examination of the spine may be disappointing in that there is often poor correlation between degenerative changes seen on x-rays and clinical symptoms (Lawrence, 1969). This method will allow accurate assessment of the movement between vertebrae. Preliminary evidence suggests that localized stiffness between adjacent vertebrae can be associated with low back pain. Narrowing of the spinal canal puts the nerve roots at much greater risk from a small prolapse or osteophyte. There may be reduction in the sagittal diameter of the canal or, alternatively, a trefoil canal with shallow lateral recesses in which an emerging nerve root is readily trapped. It is very difficult to estimate the size and shape of the canal from conventional radiographs. Even at open surgery the diagnosis can be missed as the roof of the canal is removed to expose the roots. This technique will allow accurate determination of the size and shape of the canal from a pair of radiographs.

Finally this technique allows detailed examination of radiographs in a manner not readily available by conventional means. Binocular stereovision enables examination of the apophyseal joints and observation of degenerative changes with a clarity that is not apparent when viewing either of the two radiographs in a conventional way. We have been able to identify small fractures of the pedicles that were not otherwise readily visible.

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Reference

LAWRENCE, J. S. (1969) *Ann. rheum. Dis.*, **28**, 121 (Disc degeneration. Its frequency and relationship to symptoms)