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A New Method of 3-Dimensional Localization of Intraocular Foreign Bodies Using CT Imaging: A Role of Optic Nerve

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Summary: Computed tomography (CT) is considered the most sensitive method for the detection of intraocular foreign bodies (IOFBs). The purpose of this study was to evaluate a new method of 3-dimentional (3D) localization of IOFBs that takes advantage of the anatomical structure of the optic nerve and to assess the clinical outcomes using this new method. Twenty-two trauma patients with IOFBs or suspected IOFBs admitted to our hospital were scanned with multislice CT (MSCT) between July and December 2003. All scanning was performed with a 16-row spiral CT in axial plane using a sequential scanning protocol. During the scanning, the eyeball of the patient was kept stable and was not allowed to rotate internally or externally. Section collimation was set at 16 mm × 0.75 mm. Table feed was 12 mm. Reconstruction index was 0.75 mm. After scanning, the reconstructed images were loaded into a workstation to create the multiplanar reconstruction images with the aid of the 3D software. We compared the localization results with the operative findings. Multiplanar reconstruction images showed IOFBs in all 22 patients. IOFBs occurred in the eyeball of 14 patients, in the wall of the eyeball of 5 patients and in the posterior orbits of 3 patients. Different surgical procedures were designed according to the localization by this new method and all IOFBs were successfully removed. All of these foreign bodies were metallic and the localization of IOFB using MSCT was consistent with that found by operative findings. It was suggested that MSCT is a simple and effective imaging modality for the localization of IOFBs. In our study, we localized the IOFBs more quickly and accurately by taking advantage of the fixed position of the intraocular segment of the optic nerve, and determined the necessary surgical parameters.
Key words: multislice computed tomography; intraocular foreign body; localization; optic nerve

Intraocular foreign bodies (IOFBs) are a common occurrence worldwide and have been estimated to occur in 10% to 41% of open-globe injuries[1–5]. IOFBs are a well-known risk factor for posttraumatic endophthalmitis and a wide range of other complications, including hyphema, cataract, vitreous hemorrhage, and retinal tears and detachment[6–8]. Sometimes IOFBs may even result in severe visual loss depending on a number of factors including the mechanism of injury, size and location of the IOFBs, and the occurrence of postoperative endophthalmitis and proliferative vitreoretinopathy[3, 6–9]. Metallic foreign bodies are much more common than inorganic nonmetallic foreign bodies, such as glass, plastic, and rubber, as well as organic foreign bodies such as vegetables[10, 11]. Metal is reported in 60% to 88% of IOFBs, up to 90% of which may be magnetic[12, 13]. Removal of metallic foreign bodies is important because most metal fragments are toxic to intraocular tissues and may cause tremendous chemical injuries to the eyeball if not removed in a timely manner[14]. As a result, early examination of the eye is necessary. However, the diagnosis and surgical operation of the foreign body inside the eye is a complicated, delicate work, and the position of the foreign body usually affects surgical strategies[9]. To locate the IOFB precisely before operation is essential for successful surgery. The size and shape of the foreign body also influence the surgical method and the choice of the cutting position.

X ray, ultrasound, computed tomography (CT) and magnetic resonance image (MRI) are the imaging modalities for IOFB localization[14, 15]. Among these methods, CT has a high sensitivity and is generally considered to be the gold standard for IOFBs[9, 16]. It is safe to localize metallic IOFBs using CT, exclude orbitocranial extension, and is also able to diagnose orbital wall fractures and orbital sepsis with high accuracy[17, 18]. Compared with common CT, multislice computed tomography (MSCT) has a higher identification rate, is injury-free, rapid and has a much wider variety of applications. Compared with other imaging modalities, MSCT can show the foreign body and its relation to the wall of the eyeball and neighboring structural injuries, and can be widely used in the diagnosis of IOFBs[11, 19]. However, the method of IOFB localization using MSCT nowadays has deficiencies, and sometimes causes bias. For example, when performing the localization with MSCT, using the largest scanning eye slice as the central horizontal plane of eyeball always leads to inevitable distortion if the central horizontal plane of eyeball is not parallel with the scanning slice. A better method to determine the equator of eyeball is still needed.

The optic nerve can be divided into four parts known as intraocular, intraorbital, intracanalicular and

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intracranial segments, among which the intraocular segment lies on the horizontal axis of the eyeball. Because the intraocular segment of the optic nerve is fixed on the eyeball, we considered whether IOFBs could be localized by taking advantage of the fixed position of the optic nerve.

In this study, we reported a new localization method, 3-dimensional multiplanar reconstruction (MPR) of trans-optic nerve, to determine the equator of the eyeball, which can minimize the bias of different eye positions in MSCT scanning. We assessed the accuracy and outcomes of this method by comparing the imaging findings with surgical and clinical follow-up results.

1 MATERIALS AND METHODS

Twenty-two trauma patients with IOFBs or suspected IOFBs admitted to our hospital, including 19 males and 3 females with age ranging from 9 to 41 years, were scanned with MSCT between July and December 2003. All scans were performed with a 16-row spiral CT (Somaton sensation 16, Siemens, Germany) in the axial plane using a sequential scanning protocol. During the scanning, the eyeball of the patient was kept stable and was not allowed to rotate internally or externally. Section collimation was set at 16 mm × 0.75 mm. Table feed was 12 mm. Reconstruction index was 0.75 mm. After scanning, the reconstructed images were loaded into a workstation to perform MPR with the aid of the 3D software in the following steps. For step 1, in the axial plane, the slices in which the lens or the initial part of optic nerve that attached to the eyeball was the biggest were found. They may or may not be in a same axial slice. A line Z passing through the center of the lens and the center of initial part of the optic nerve was drawn (fig. 1A). Then in the sagittal plane, the line Z was finely adjusted and passed through the center of the lens and the initial part of the optic nerve (fig. 1B). Thus, the axial plane of the line Z could be regarded as the equator of the eyeball. For step 2, in the axial plane of line Z, a line Y which passed through the middle point of the external cornea and perpendicular to line Z was drawn (fig. 1B). For step 3, then again, the location of line Z was adjusted to make it pass the center of the lens so that the eye slice could be divided equally. Thus line Z could be regarded as the geometric axis and central axis of the eyeball. Then another location line X which passed through the external part of the cornea and met with Z vertically was drawn (fig. 2). For step 4, in the coronal plane, the Z stalk was followed to turn over the page level up in the corona, then whether line X and line Y divided the eye frame equally was observed. And then whether there exists lateral displacement when line X and line Y moved synchronously (through the line of fixed position) at the horizontal position and sagittal position was also observed (fig. 3). All artificial methods cannot avoid errors, but in this way, we could check and fix whether the anterior steps had the error or not. Obviously, if it had moved a little bit, we could adjust appropriately until it did not have obvious movement. For step 5, the page was turned over to differentiate the sagittal position, axial position and coronal position which in turn to locate the biggest level of foreign body. And then the image was saved (fig. 4). For step 6, the saved image was opened in the view window in order to measure the foreign body and the distance of the three fixed lines, the perpendicular distance between the foreign body and the external cornea, and the perpendicular distance between top and bottom to the axis. For step 7, in the largest layer of the coronal plane, after the biggest foreign body of 3D was located, then the function of Radil Rauges was opened so that the district was divided at 30 degrees and the eye frame was divided equally. Then a view fixed position of the foreign body was kept in the district and the time position and the longitudinal position of the foreign body was located (fig. 5). For step 8, after scanning, the multiplanar reconstruction (MPR) image was obtained and by using a volume rendering technique (VRT), the foreign body would be more concrete, which in turn provided more spatial understanding of the foreign body (fig. 6).

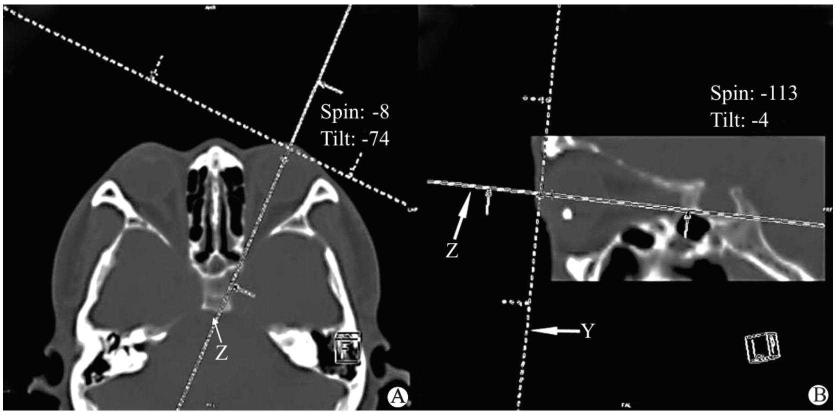

Fig. 1 Establishment of line Z and line Y

A: Line Z was drawn and adjusted to pass through the center of lens. B: Line Y which passed through the middle point of the external cornea and perpendicular to line Z was drawn.

2 RESULTS

MPR images showed IOFBs in all the 22 patients. Fourteen IOFBs were in the eyeball, 5 in the wall of the eyeball, and 3 in the posterior orbits respectively. Different surgical procedures were designed according to localization revealed by this new method and all IOFBs were successfully removed. All of these foreign bodies were metallic and the localization of the IOFBs using MSCT was consistent with that found by the operative findings.

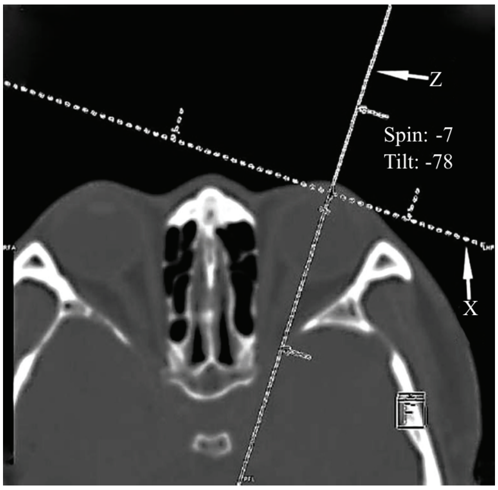

Fig. 2 Establishment of line X and Z
Line X was drawn to pass through the external part of corneal and met with Z vertically.

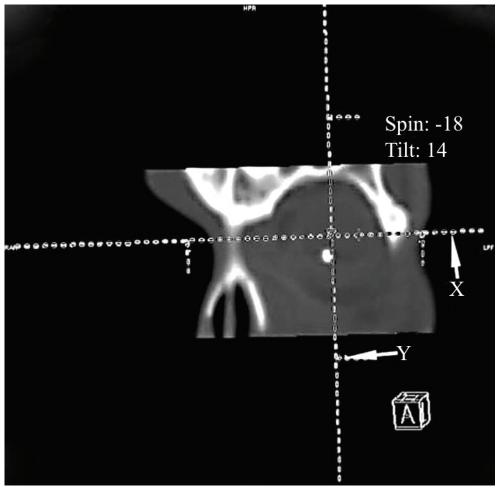

Fig. 3 Establishment of line X and Y
Line X and line Y were adjusted to divide the eye frame equally.

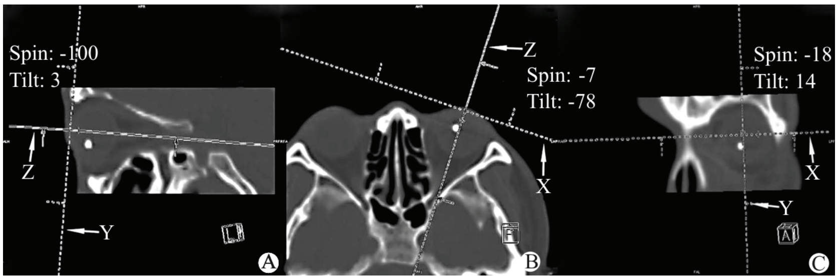

Fig. 4 Location of the foreign body
A: sagittal position; B: axial position; C: coronal position

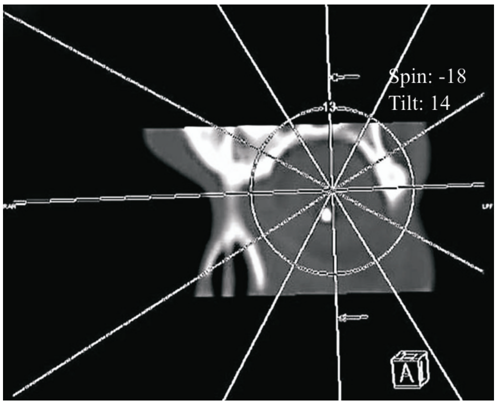

Fig. 5 The district where the foreign body located was divided at 30 degrees equally.

Fig. 6 VRT for the location of the foreign body
The foreign body was more concrete by using VRT in a MPR image by adjusting the tint and spin of the image.
A: (spin, -2; tilt, 0); B: (spin, 32; tilt,74); C: (spin, 0; tilt, 0)

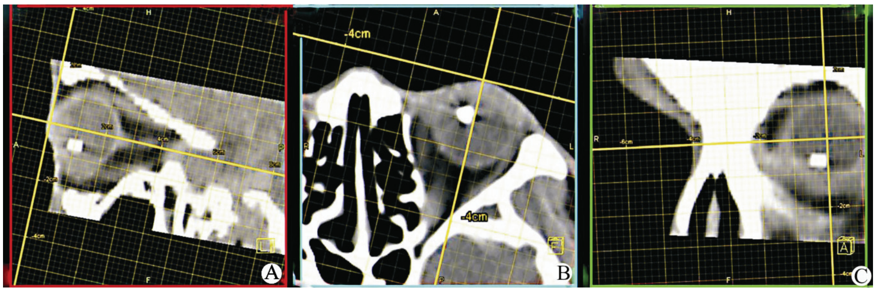

Fig. 7 Establishment of the rectangular coordinate system in the 3D picture of the biggest layer of the foreign body
A: sagittal position; B: axial position; C: coronal position

3 DISCUSSION

IOFBs, a particularly significant and distinct subset of open globe injuries, may cause severe visual loss with serious complications such as endophthalmitis and retinal detachment[3, 6–9]. Localization of IOFBs with the aid of medical imaging modalities has been done for over 100 years. About 80 methods of IOFB localization have been reported. In the last three decades, with the invention and application of ultrasound, CT and MRI, these techniques have gradually been applied into the localization of IOFBs[20, 21]. Among those imaging modalities, CT has played a role as the first-line imaging method for the diagnosis of patients with IOFBs or suspected IOFBs[9, 11, 16]. Compared with other imaging modalities, MSCT can show the foreign body and its relation to the wall of the eyeball, to the accompanying neighbor structure, and can be widely used in the diagnosis of IOFBs[11, 19]. The most important thing in the localization of IOFBs is to define the X, Y, Z axis of the eyeball. The secondary eye position is found in most trauma patients who are sent to the hospital, in which case the eyeball may rotate in different directions. Thus, an angle will always exist between the scanning surface and the eyeball's horizontal face no matter what kind of criterion line is adopted during the scanning, even if the eyeball is kept fixed.

Currently, many protocols for the localization of IOFBs regard the largest slice of eyeball and the clearest plane of lens as the central horizontal plane. However, there have been reports in the literature that errors and bias may occur by this kind of method, which may lead to severe consequences[22, 23]. In our study, we defined the eyeball's horizontal plane as the one that included the center of the lens and the starting point of the optic nerve. The optic nerve can be divided into four parts known as intraocular, intraorbital, intracanalicular and intracranial segments. Of these, the intraocular segment lies on the horizontal axis of the eyeball. The macula lutea is located in the central portion of the retina, while the optic disk is located approximately at the same level as the macula lutea[24, 25]. If the eyeball does not rotate laterally and medially around the A-P axis, the transverse plane through the lens center and the starting point of optic nerve could be regarded as the horizontal plane of the eyeball (Z axis). The plane that is perpendicular to this horizontal plane and evenly splits the eyeball is the vertical plane of eyeball (Y axis). But if the patient's eye rotates externally and internally around the Z axis, there has been no method precise enough to locate an IOFB at present. So it is critical to keep the eyeball fixed during the scanning. In our study, the new method which takes advantage of the position of the optic nerve can localize the IOFBs accurately no matter what direction the eyeball rotates around Y axis and X axis, as long as there is no lateral or medial rotation around the Z axis. This is essential for the successful diagnosis of the IOFBs. As long as the patient's eye is kept looking in a fixed direction, we can localize the foreign body quickly and accurately through the optic nerve localization method.

After setting up the 3D coordinator in the biggest layer of 3D coronal plane foreign body, the function of the Radil Rauges was opened. On the Rauges function dialog box, the eye slice was divided equally in 30 degrees distance and the time position or the longitudinal position of the foreign body was fixed, which would make it easier for the doctor to master the anatomical position of the foreign body (fig. 5).

Moreover, a rectangular coordinate system could be established in the 3D picture of the biggest layer of the foreign body. Thus, more concrete data of the position of the foreign body could be provided to the doctor (fig. 7).

The reconstruction of VRT can make the foreign body more concrete on the images, especially the VRT pictures after scanning, which provides a more concrete and accurate understanding of the localization of the foreign body. With the aid of VRT, more necessary parameters can be provided for clinical operations[26, 27].

In conclusion, MSCT is a simple and effective imaging modality in the localization of IOFBs. In this study, we took advantage of the anatomic structure of the optic nerve to localize the IOFBs and created MPR images of the foreign bodies. After comparison with operative findings, we found that the position of the IOFBs localized by this new method was consistent with the operation. Hence, we concluded that by taking advantage of the fixed position of the intraocular segment of the optic nerve, we can localize IOFBs more rapidly and accurately, and determine the necessary surgical parameters.

Conflict of Interest Statement

The authors declare that there is no conflict of interest with any financial organization or corporation or individual that can inappropriately influence this work.

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