A Formula for Calculating Deviation of Computed Tomography-Guided Puncture Point

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To the Editor: Computed tomography (CT) is a common guiding method in clinical practice for percutaneous biopsy and treatment.[1-3] The key of CT guidance is how to calculate the bed coordinates corresponded to the diagram layer coordinates. The author found that the position of the puncture point is completely correct when gantry angle is 0°. Otherwise, it would have deviation and which can consistently augment as the angle increases. In this case, doctors need to perform CT scan to correct the error and meet the puncture point for many times, which obviously increases the operation time for operators and radiation dose for patients[4] and further brings the intraprocedural risk and complications in patients undergoing CT-guided percutaneous biopsy and treatment.[5] The cause of deviation was usually attributed to patient's movement. Nevertheless, the author found that the deviation was mainly caused by CT itself in a large number of clinical practices. Furthermore, according to the geometric principles of CT-guided puncture, the functional relation between the diagram layer coordinates and the bed coordinates can be derived using a variable θ to describe the slant angle of gantry. Therefore, this study aimed to explore the method to calculate the CT-guided puncture point by introducing the variable of gantry slant angle.

All procedures in this study were approved by the Ethics Committee of the 117 Hospital of the Chinese People's Liberation Army. Informed written consent was obtained from all patients before their enrollment in this study.

This study included 401 patients who underwent CT-guided puncture examination and treatments in the 117 Hospital of the Chinese People's Liberation Army from October 2002 to October 2016. There were 258 males and 143 females, and the mean age was 52.7 ± 13.8 years (range: 12–87 years). Among them, 178 cases were related to CT-guided percutaneous biopsy, 124 cases lumbar discography, 46 cases percutaneous lumbar intradiscal annuloplasty, and 53 cases percutaneous vertebroplasty. Both the thickness and layer spacing were 3 mm on average; the gantry slant angle θ ranged from 0° to 20° (forward or backward). Thus, CT-guided puncture examination and treatments can be carried out when doctors use external positioning.

The geometric principles of position system of CT scanner (Prospeed F II; General Electric Medical Systems, Milwaukee, Wisconsin, USA) were as follows: (1) Inner and external position system: GE Prospeed F II CT scanner uses double-plane laser to both inner and external positions. The axial plane of the inner position is the tomography plane of CT, while the external position sets an anatomy reference point for patients to scan position. The distance between these two cross-sections is 190 mm [Figure 1a]. (2) The bed coordinates [Figure 1b]: The inner located N-point is the original point. The value of bed coordinates reveals the distance from each point to the N-point. S and I represent the points on the bed relative to the outside and medial sides of the N-point separately. In general, after the external reference point (W) set, the value of bed coordinates is S190. In Figure 1b, if we move the reference point W to A-point, the value of bed coordinates would be I150. Similarly, if we move the reference point W to B-point, the value of bed coordinates would be S350. Obviously, the value of bed coordinates is the distance from each body point to the original N-point with the reference point set. (3) The diagram layer coordinates: it is different from the bed coordinates. W-point is the original point and is the body reference point that is set by the external positioning line. S and I refer to head side and foot side (by CT acquiescent, head goes into first), respectively, and their coordinate values are distances from each body point to body reference point W. As shown in Figure 1c, the values of diagram layer coordinates of N-point, W-point, A-point and B-point are S190, S0, S340, and I160, respectively. (4) When gantry slant angle is 0°, Figure 1b and 1c combined, it could be found that the distance of two coordinates' original points is 190 mm and the directions are inversed. The following formula could be derived: T = S190–M; where T is the value of bed coordinates and M is the value of diagram layer coordinates; and the value is positive with S and negative with I.

Generally, the actual puncture point is located at the external positioning point in clinical. It requires calculating the value of bed

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coordinates (T_{WM}) after the target layer moving to W-point [Figure 1b]. According to the core of the diagram layer coordinates, T_{WM} is the value of bed coordinates after moving the diagram layer coordinates of M, relative to S190. Thus, the following formula could be derived: T_{WM} = S190 + M, where M is the value of the diagram layer coordinates; and the value is positive with S and negative with I. T_{WM} is the value of bed coordinates after the related diagram layer moving to the external locating point.

As showed in Figure 1d, the gantry slant angle is θ (θ>0°). If the projection point of external locating line comes at point W', the length of W'N' is equal to W'N, which is obviously contradicted with the theorem that the hypotenuse of right triangle is longer than either right-angle side. Thus, it is impossible to constantly keep the distance of inner and external locating points 190 mm. Only that the projection point of external locating line moves to W-point can keep WN = W'N' (when gantry slant angle is 0 degree, W is W'). Therefore, the result of the above second equation must have a few deviations. According to the trigonometric function theory of WN' = WN/Cosθ = S190/Cosθ and combining with equation of T_{WM} = S190 + M, the formula could be derived: T_{WM-1} = S190/Cosθ + M, where θ is gantry slant angle, and only in the range of I20–S20, it has significance (S represents gantry slanting toward head direction; I represents gantry slanting toward foot direction) in GE Prospeed F II CT scanner. M is the value of the diagram layer coordinates. T_{WM-1} is the value of bed coordinates after the related diagram layer moving to the external locating point.

In the triangle WNN' shown in Figure 1d, Cosθ = WN/WN' = 190/(WW' + 190), if θ is the gantry slant angle and X stands for the deviation of WW', deviation can be calculated as: X = |190(1/Cosθ – 1)|.

The gantry slant angle reaches 0°: As showed in Figure 1c, the value of the diagram layer coordinates of A is S340, then we can use the second equation to calculate the related bed coordinates value T_{WM} which is S530. When the value of bed coordinates showed S530, W-point marked by external locating point is consistent with A-point on diagram layer, which represents the puncture point of skin. Then place an opacity marker on A-point to confirm the accuracy of the puncture point with CT scanning repeatedly. The results demonstrated that the actual puncture point corresponds with the value of bed coordinates calculated by the second equation.

The gantry slant angle is equal to 5°, 10°, and 20°: In order to test the accuracy of the Equation 3 when the gantry slant angle is not equal to 0°, we set the angle to be 5°, 10° and 20°. As shown in Figure 1c, when the gantry slant angle is 20°, the M of A-point is S340; however, if we use Equation 2, the value of T_{WM} is S530. Using the same test method as the angle is 0°, the puncture point moves. After scanning some layers by CT, it will display the right puncture point and the actual bed coordinates should be at S542.1, and the actual position error is 12.1. While we use Equation 3 to calculate the value of bed coordinates, T_{WM-1} = S190/Cos20° + S340 = S202.12 + S340 = S542.12, which just corresponds to the actual bed coordinates. Similarly, there is a perfect match between the bed coordinate figures of puncture points and the results of Equation 3 when the angles are 5° and 10° [Table 1]. As showed in Table 1, the calculations fit perfectly with the actual points of the bed coordinates, as well as the error when the decimal point keeps one bit. With the increase of the angel, the error increases.

CT-guided percutaneous biopsy and interventional treatment have numerous advantages, such as high accuracy of position, little damage of tissue, little pain of patients, and wide use in clinical practice.[1,3,6] There is no need to rotate the gantry angle (θ = 0°) for most of the patients, when they undergo needle biopsy guided by CT. But when it needs to turn angles, the author found that it was hard to confirm the right puncture point according to Equation 2. It is Equation 3 that indicates the certain function relation

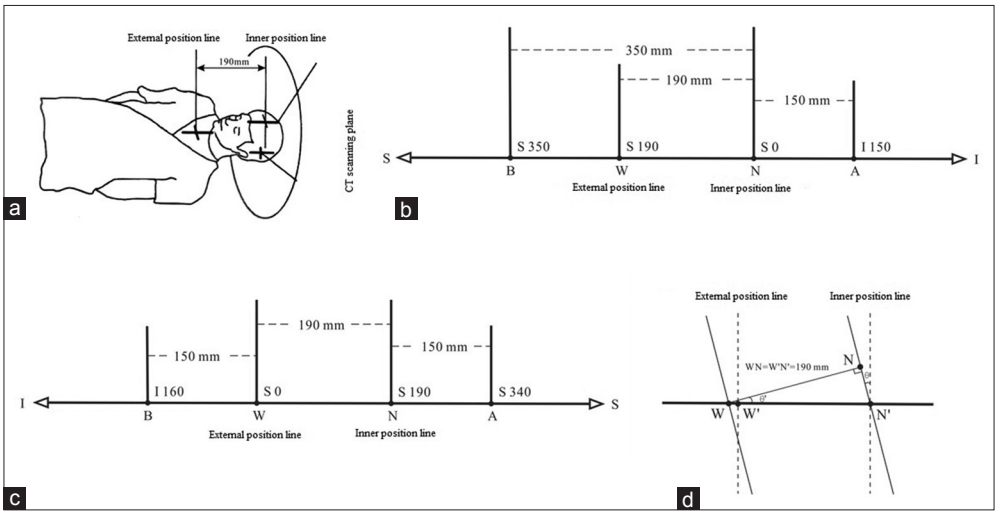

Figure 1: (a) Diagram of the inner and external position system. (b) Illustration of the bed coordinates. (c) Illustration of the layer coordinates. (d) Diagram of variation in internal and external positioning system with a gantry slant angle (θ).

Table 1: Relationships of T_{WM-1} and real bed coordinates, error, and real error

Angles	T_{WM} (mm)	T_{WM-1} (mm)	Error (mm)	Real bed coordinates (mm)	Real error (mm)	Accurate rate (%)
0°	530	530.0	0.0	530.0	0.0	100
5°	530	530.8	0.8	530.8	0.8	100
10°	530	532.9	2.9	532.9	2.9	100
20°	530	542.1	12.1	542.1	12.1	100

between the bed coordinates and the diagram layer coordinates. In this equation, 1/Cosθ can be expressed as the correct coefficient of gantry slant angle, indicating the change rate of the distance between inner and external positioning reference plane of CT in the horizontal plane. When θ is 0, Cosθ = 1, and Equation 3 can be reduced to be Equation 2. That is why it can calculate the right located point by Equation 2 when the gantry slant angle is 0.

In this study, the successful application of 200 patients has further verified the reliability of the formula (Equation 3) in clinical practice since it was discovered in 2007. If the discovery applied to the manufacturing process of CT equipment, the error could be correct by CT itself when the gantry angle is not 0°. After the quality of CT equipment is improved, it is not only convenient for doctors in the CT-guided diagnosis and therapy, but also beneficial to the patients for reducing radiation dose and iatrogenic injury. Therefore, it is considered there is a broad application prospect for the discovery.

As mentioned above, by introducing the variable of gantry slant angle in Equation 3, the figures that calculated by the geometrical principle of Equation 3 could completely correspond with the actual bed coordinate figures, that was the puncture points. Equation 3 could accurately calculate the bed coordinate figure of target diagram layer for quickly positioning puncture point. After a large number of clinical practices, it was proved that the calculation method was fast and accurate, and this discovery is worth reference for the same trade.

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Conflicts of interest

There are no conflicts of interest.

References

1. Chang CY, Kattapuram SV, Huang AJ, Simeone FJ, Torriani M, Bredella MA, *et al.* Treatment of aneurysmal bone cysts by percutaneous CT-guided injection of calcitonin and steroid. Skeletal Radiol 2017;46:35-40. doi: 10.1007/s00256-016-2503-7.
2. Kato T, Sugiyama T, Matsushita Y, Suzuki T, Motoyama D, Matsumoto R, *et al.* Evaluation of CT-guided percutaneous needle biopsy for diagnosis of renal tumor. Hinyokika Kiyo 2017;63:51-6. doi: 10.14989/ActaUrolJap_63_2_51.
3. Yin Z, Liang Z, Li P, Wang Q. CT-guided core needle biopsy of mediastinal nodes through a transpulmonary approach: Retrospective analysis of the procedures conducted over six years. Eur Radiol 2017;27:3401-7. doi: 10.1007/s00330-016-4718-3.
4. Prosch H, Stadler A, Schilling M, Bürklin S, Eisenhuber E, Schober E, *et al.* CT fluoroscopy-guided vs. multislice CT biopsy mode-guided lung biopsies: Accuracy, complications and radiation dose. Eur J Radiol 2012;81:1029-33. doi: 10.1016/j.ejrad.2011.01.064.
5. Iezzi R, Larici A, Contegiacomo A, Congedo MT, Siciliani A, Infante A, *et al.* A new score predicting intraprocedural risk in patients undergoing CT-guided percutaneous needle pulmonary biopsy (CATH-score). Eur Rev Med Pharmacol Sci 2017;21:3554-62. doi: 10.26355/eurrev_201708_13265.
6. Yan GW, Bhetuwal A, Yan GW, Sun QQ, Niu XK, Zhou Y, *et al.* A systematic review and meta-analysis of C-arm cone-beam CT-guided percutaneous transthoracic needle biopsy of lung nodules. Pol J Radiol 2017;82:152-60. doi: 10.12659/PJR.899626.