Article published online: 2022-09-14

Original Article

Gravity-guided Stereotactic Brain Biopsy

Abstract

Introduction: This study describes a technique using gravity for guidance in stereotactic brain biopsy. This will be especially useful in hospitals where the stereotactic equipment is unavailable. **Objectives:** The aim of this study is to describe the technique, develop a formula to define its limits of accuracy, and report on its clinical application. **Methods:** Using the positioning laser grid lines on the computed tomography scanner, a small metallic marker is placed on the scalp at the intended biopsy site. The distance between the tumor and the inner table of the bone is measured. In the operating theater, the patient is positioned such that the tip and the bridge of the nose are aligned in a horizontal position. The patient's two eyebrows or the orbital canthi are aligned in a vertical line. Simultaneously, the posterior borders of the two pinnae are aligned vertically. Gravity is used to guide the biopsy needle through the marked burr hole into the target. Seven patients had biopsies. One was for targeting the craniopharyngioma cyst to place an Ommaya catheter. The fraction of error or error fraction (EF), $\frac{E}{a} = \frac{x}{a} \tan \alpha - 1$ was developed for verification of its limits of accuracy. **Results:** All the biopsies were diagnostic and the Ommaya catheter was correctly sited. The EFs at $\alpha = 5°$ were all predictive of the limits of accuracy of this technique. **Conclusion:** This is the first reported gravity-guided stereotactic brain surgery. The outcome in all the eight cases showed that it was within the limits of its accuracy. EF can be calculated to ensure accuracy. This technique is helpful if a commercial stereotactic system is not available.

Key words: *Developing country, gravity-guided, stereotactic biopsy*

Albert Sii-Hieng Wong, Vincent Boon-Hean Chen[1]

Department of Neurosurgery, Sarawak General Hospital, [1]Department of Radiology, Timberland Medical Center, Kuching, Sarawak, Malaysia

Introduction

Both the frame-based and the frameless stereotactic (navigation) systems are currently used for biopsy of intracranial tumors. However, all these equipment are very expensive.[1,2] We describe a stereotactic biopsy technique without the use of a frame-based or a navigation system. The technique uses gravity to guide the stereotactic operation. This will be particularly useful in the developing countries where the neurosurgical navigation equipment is not easily available. The tumor size in such population is usually large at presentation, frequently requiring formal craniotomy and excisional biopsy. However, when a patient presents with a small deep-seated tumor, a stereotactic biopsy is still preferred as a less invasive procedure when compared to an open craniotomy.[3]

Methods

The principles of this technique

Before the advent of definitive stereotactic system, a lesion near the surface of the brain could be biopsied by putting a small metallic marker over it on the scalp.[4] The closer the lesion is to the surface of the brain, the more accurate is the biopsy.[5] A computed tomography (CT) scan can be used to correctly place the marker over the lesion.[6] However, when the lesion is located deeper from the surface, the inaccuracy in determining its position increases.

This error E or deviation can be described by the mathematical formula using trigonometry:

$$E = x \tan \alpha - a$$

The error fraction (EF) is:

$$\frac{E}{a} = \frac{x}{a} \tan \alpha - a$$

E is the distance away from the edge of the tumor with a radius of a. E has a positive value or error is present if the tip

How to cite this article: Wong AS, Chen VB. Gravity-guided stereotactic brain biopsy. Asian J Neurosurg 2018;13:626-30.

Address for correspondence:
Dr. Albert Sii-Hieng Wong, Department of Neurosurgery, Sarawak General Hospital, Jalan Hospital, Kuching, Sarawak 93586, Malaysia.
E-mail: wonghm96@yahoo.com

Access this article online

Website: www.asianjns.org

DOI: 10.4103/1793-5482.238075

Quick Response Code:

is outside the tumor. It is zero at the edge of the tumor and negative if it is inside the tumor. *X* is the depth from the inner margin of the burr hole. α is the allowance given to the deviation of the angle of the biopsy needle from the vertical [Figure 1].

When the head is positioned laterally and viewed face on, two sets of orthogonal lines can be drawn. One is the horizontal line through the tip and the bridge of the nose (Line A). The other is the perpendicular line through the two eyebrows or the outer canthi of the eyes (Lines B and B'). Looking from the top of the head, a line can be drawn so as to join the posterior borders of the two pinnae as in Line C [Figure 2].

From the frontal view, Line A is then aligned to an adjacent horizontal surface like a trolley top. Simultaneously, Line B should be aligned perpendicular to the horizontal plane.

Next inspecting now from the vertex of the head, both Line B and Line C are adjusted such that both are perpendicular to the horizon. The head can then be said to be truly positioned with the falx being horizontal using these lines.

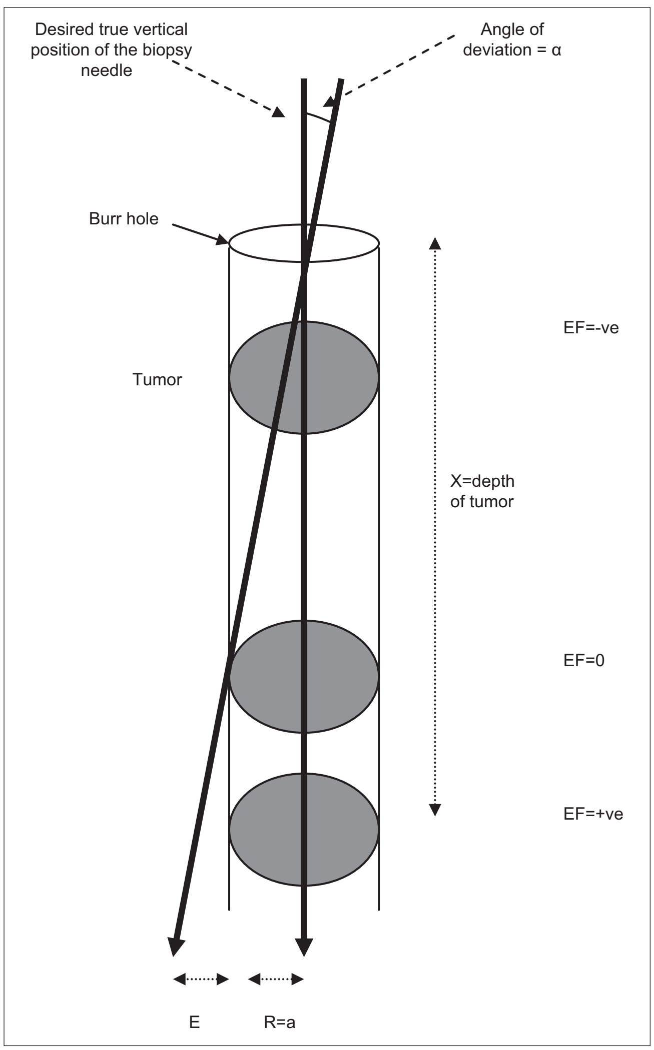

Figure 1: Derivation of the formula; $E = x \tan \alpha - a$

Hence, when a biopsy needle is passed vertically, it will hit the lesion through the midpoint of the marked burr hole.

This vertical line can be obtained by using gravity and utilizing the two plumb lines set up in the vicinity. The biopsy needle can also be aligned to the two plumb lines using the two perpendicular planes of sight from the needle to each one of the plumb lines.

In the computed tomography scanning room

The first step is to get the trajectory of the biopsy needle. The scalp area over tumor is shaved. The patient is placed in the supine position on the CT table with care being taken to ensure that the head is placed symmetrically in the sagittal plane. Axial scans are obtained, and the slice showing the optimal plane for biopsy is chosen by the neurosurgeon. With the aid of the CT machine laser positioning light gridlines, the skin is marked with a line in the axial plane with an oil-based marker pen. An array of hypodermic needles is placed over the tumor site, and the patient is rescanned [Figure 3]. The optimal skin entry site for the biopsy needle is then determined relative to the needle array. The skin location is chosen so that the line of biopsy through the tumor lies perpendicular to the falx cerebri. The skin biopsy site is marked and a small metallic marker is taped over it. A scan is performed to show the desired skin metallic marker position relative to the tumor. The distance along this perpendicular line from the falx, between the tumor and the inner table of the bone, is measured from the CT console directly. This is called distance *x*.

To get the distance *x*, the images are first adjusted in the axial and the coronal planes on the CT scanner such that both the right and left sides of the brain are symmetrical. This can be done using the multiplanar rotation (MPR) software that is routinely available on the CT console. Both the axial and the coronal cuts can be rotated until the falx is exactly at midline [Figure 4]. The patient then has a final check CT with a single marker before being sent to the operating room as shown in Figure 4 with a single marker.

In the operating room

This step requires the use of gravity for guidance of the biopsy needle. The head is placed laterally so that

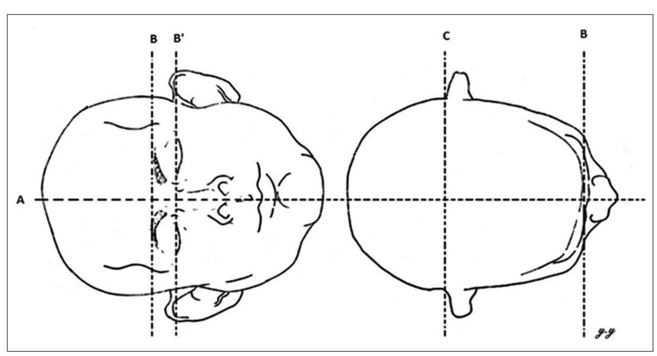

Figure 2: Lines used to position the falx horizontally

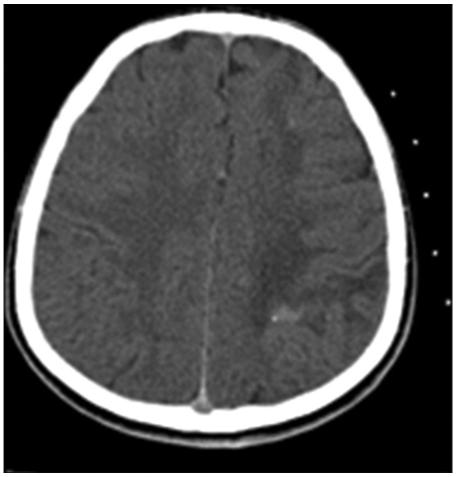

Figure 3: Needle array placed over the biopsy site

the falx is positioned in the horizontal plane using the Mayfield clamp. The contralateral shoulder needs to be raised to allow the lateral turning of the head. By using the facial contours including the bridge of the nose (line A), the eyebrows (Line B), the canthi (Line B'), and the pinnae (Line C), this horizontal positioning can be achieved using the tilting ability of the operating table. The table can be tilted either to the left or the right and put in Trendelenburg or reverse Trendelenburg to place all the Lines A, B or B', and C such that they are parallel or perpendicular to the horizon, respectively.

Using available equipment such as the Greenberg retractor system, a plumb line is set up using a weight on a sterile silk tie. A plumb line hung from a drip stand outside the sterile field is equally good for this purpose. The biopsy needle is then held using the second retractor arm and the blade holder. A small straight plastic tube of the diameter that fits the biopsy needle is clamped onto the second blade holder. This can be done by improvising from a variety of plastic sheaths available in the operating room. The biopsy needle can then be navigated through this tube.

The operative procedure

A burr hole is then sited under the scalp position marked by the metallic marker obtained from the planning CT scan. The biopsy needle is then inserted through the plastic tube holder held by the Greenberg blade holder. This needle is aligned at two right angle planes with the plumb lines set up from the other Greenberg retractor arm or one outside the operative field on a drip stand. The arm is then locked holding the biopsy needle in the vertical position [Figure 5]. The biopsy needle is then inserted to the distance (x) from the inner table of the burr hole into the center of the tumor. A postoperative CT scan in Figure 6 shows the biopsy needle hitting the lesion with a track perpendicular to the falx and an air bubble lying at the end of the track.

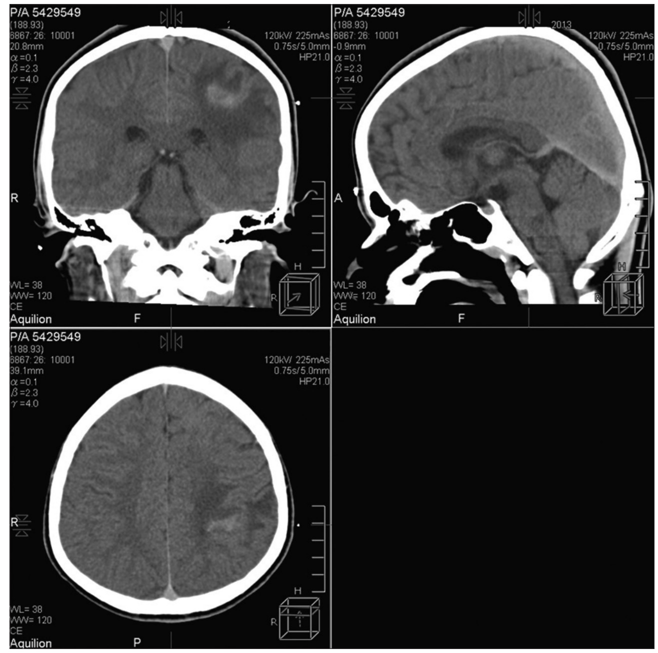

Figure 4: Preoperative computed tomography showing the left parietal enhancing lesion with the marker over it

Results

The formula $\frac{E}{a} = \frac{x}{a}\tan\alpha - 1$ indicates that for an angle deviation α, the error E is proportional to the depth of the tumor x. The deeper the tumor, the greater the possible needle deviation from the edge of the tumor. Any distance between zero to negative a falls within the radius of the tumor. Thus, E has a negative value if the tip of the biopsy needle is inside the radius of the tumor. If it is positive, then the tip is located outside the radius of the tumor. Likewise, a negative or zero EF means that the needle will hit the target. Any positive EF will indicate that the needle passes outside the radius of the tumor. Thus, if the biopsy needle deviates 5°, then the angle α is 5° (tan 5° is 0.087). If the depth x is 5 cm, then for a tumor with a radius of 0.5 cm, the EF is −0.125. It means that if the biopsy needle deviates at 5° off vertical, it will still hit the tumor [Figure 1].

We utilized this technique on 8 consecutive patients from 2011 to 2015. Seven had biopsies and one had an insertion of Ommaya reservoir catheter into the cyst of a craniopharyngioma. All were on target as the biopsies were all diagnostic with two cases of astrocytoma, four cases of cerebral lymphoma, and one case of cysticercosis. Postoperative CT scan showed the accurate placement of the catheter into the cyst in the fourth case. There was neither morbidity nor mortality. The mean depth of the biopsies was 36.6 mm while the mean size of the lesions was 10.8 mm. The results are summarized in Table 1 for the diagnosis, depth from the skull, radius of the lesions, and the EFs at a biopsy angle with an allowance of 5° deviation. The negative EF means that the needle was on target for each of these cases. This concurred with the histology reports as they were all diagnostic. Figure 7 shows the H and E staining of the Taenia Solium in case 5.

Discussion

The current frame-based biopsy systems provide a high rate of diagnosis ranging from 89.3% to 96%.[7-9] The frameless system gave a diagnostic yield of 88.9%.[10] However, all these require specialized and usually expensive equipment. Although our number of cases is small, we achieved diagnoses in all the seven cases and accurate placement of the shunt catheter in one case. Previously, various techniques were devised including placement of surface wires and marker on the scalp,[2,4] CT scan-guided biopsy in the CT room,[11] and free-hand burr holes procedure.[12] This technique of using gravity to guide a biopsy needle has not been previously described for the use in intracranial biopsy. It is especially useful in developing countries where there are cost constraints.

Targeting an intracranial point using a predetermined site or direction is routinely performed in neurosurgery, although this may not be entirely accurate. The examples for this are Kocher's point for the insertion of a frontal external ventricular drain and the insertion of the ventricular end of a ventriculo-peritoneal shunt through the Keen's point. The difference between the insertion of a ventriculo-peritoneal shunt and a biopsy is that the target of the ventriculo-peritoneal shunt, which is the entry into the ventricle, can be confirmed with the egress of cerebrospinal fluid. In biopsy, this is not present for confirmation. Hence, a guidance system is essential. There were seven cases of biopsy in this series.

The advantage of this technique is that the biopsy can be done without the need to acquire costly new instruments.[1,2] This technique utilizes existing operating instruments. CT scanners are widely available nowadays with MPR software for preoperative planning and marking. All these make brain biopsy possible without any additional expensive instruments except for the disposable Nashold® biopsy needle.

Moreover, using the EF calculation, the surgeon can preoperatively know his/her accuracy by allowing for a particular angle of deviation. This is set at 5° for this discussion. This helps to make allowance for angular deviation for both the biopsy needle and the horizontal placement of the head. However, the deviation would be expected to be much <5° due to the small angle of resolution for the human eyes. This is because the angle of resolution is 1 min of an arch using the naked eye for two points in space.[13] This equation will provide a good degree of confidence for each case even at the planning stage prior to the surgery.

The disadvantages of this technique include inaccuracy in the making of the burr hole as it is done with a skin

Table 1: Clinical outcome with diagnosis, depth, radius of the lesions, and error fraction

Diagnosis	Depth (X mm)	Radius (a mm)	EF
Astrocytoma	53	7.5	−0.38
Lymphoma	39	14.5	−0.76
Lymphoma	60	12.5	−0.58
Craniopharyngioma	40	10	−0.65
Cysticercosis	29	4	−0.37
Lymphoma	35	15	−0.80
Lymphoma	38	10	−0.669
Astrocytoma	35	12.5	−0.70
Mean	36.6	10.8	All negative

EF – Error fraction

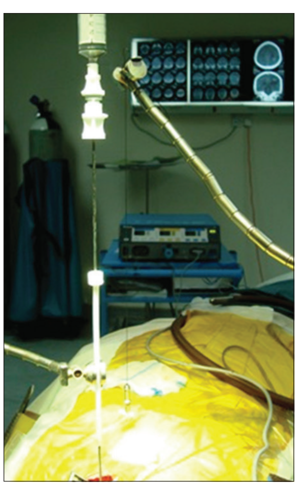

Figure 5: The biopsy needle being aligned against the silk thread hanging vertically down by gravity

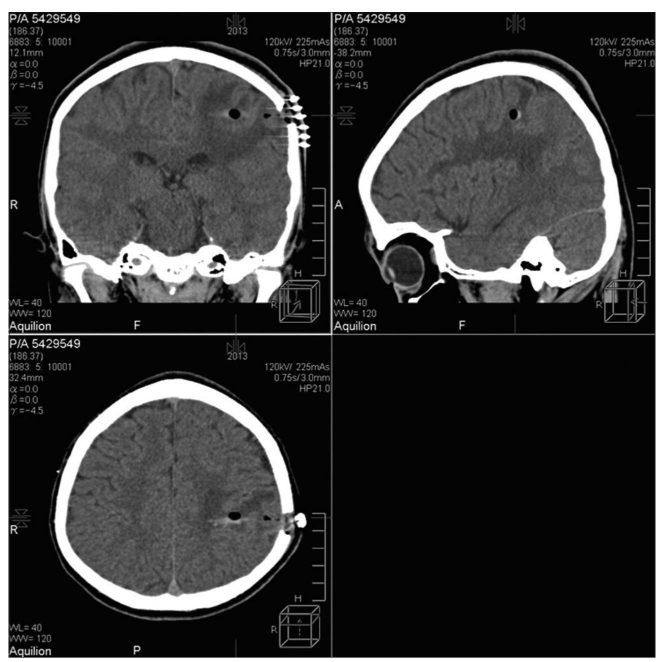

Figure 6: Postoperative computed tomography scan showing the burr hole and the needle track hitting the lesion

Figure 7: H and E stain of the Taenia Solium from the brain biopsy of case 5

marking with some mobility. This can be partly overcome by placing the Mayfield clamp away from the intended burr hole site. The position of the mark on the skin and the point to do a burr hole on the skull can be discrepant as the incision will have to go through the mark. This can be minimized by using a small stab incision and first marking the underlying bone with a twist drill.[2]

There is no ability to angulate to avoid eloquent area such as the motor cortex or the Sylvian fissure, which can be done with a formal stereotactic frame. Lesion immediately medial to the ventricle will require traversing the ventricle before getting the biopsy making it less suitable. Anatomically, if there is asymmetry of the land marks mentioned such as the eyebrows or the pinnae due to congenital malformation, then this method cannot be used.

Conclusion

This is the first reported gravity-guided stereotactic brain surgery for brain biopsies and Ommaya catheter placement. The outcome in all the 8 cases showed that the biopsy needles were on target with all the biopsies being diagnostic and the accurate positioning of the catheter. EF can be calculated to ensure the limits of accuracy. This technique is very helpful if a commercial stereotactic system is not available, especially in the context of a developing country.

Acknowledgment

We would like to thank the staff nurse Elisha Storie for developing the plastic tube, which carries the biopsy needle, Dr. Goh Chin Hwee for the line diagram in Figure 2, and Professor Pathmanathan Rajadurai, for the slide on the Taenia Solium.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Jones AP, Sofat A, Davis CH, Denton S, Gurusinghe NT. A low cost modification of an old Leksell stereotactic frame to allow CT-guided stereotaxy. Br J Neurosurg 1990;4:193-7.
2. Moseley JI, Giannotta SL, Renaudin JW. A simple, inexpensive technique for accurate mass localization by computerized tomography: Technical note. J Neurosurg 1980;52:733-5.
3. Chandrasoma PT, Smith MM, Apuzzo ML. Stereotactic biopsy in the diagnosis of brain masses: Comparison of results of biopsy and resected surgical specimen. Neurosurgery 1989;24:160-5.
4. Tariq M, Kellerman J. CT guided surface localization of brain tumours. J Postgrad Med Inst 1991;5:13-5.
5. Penning L. CT localization of a convexity brain tumor on the scalp. Technical note. J Neurosurg 1987;66:474-6.
6. Constantini S, Pomeranz S, Gomori JM. CT localization of brain tumor. J Neurosurg 1987;67:787-8.
7. Whittle IR, Denholm SW, Elshunnar K. CT-guided stereotactic neurosurgery using the Brown-Roberts-Wells system: Experience with 125 procedures. ANZ J Surg 1991;61:919-28.
8. Shastri-Hurst N, Tsegaye M, Robson DK, Lowe JS, Macarthur DC. Stereotactic brain biopsy: An audit of sampling reliability in a clinical case series. Br J Neurosurg 2006;20:222-6.
9. Pell MF, Thomas DG. The initial experience with the Cosman-Roberts-Wells stereotactic system. Br J Neurosurg 1991;5:123-8.
10. Dammers R, Haitsma IK, Schouten JW, Kros JM, Avezaat CJ, Vincent AJ. Safety and efficacy of frameless and frame-based intracranial biopsy techniques. Acta Neurochir (Wien) 2008;150:23-9.
11. Wen DY, Hall WA, Miller DA, Seljeskog EL, Maxwell RE. Targeted brain biopsy: A comparison of freehand computed tomography-guided and stereotactic techniques. Neurosurgery 1993;32:407-12.
12. Macarthur DC, Tsegaye M, Byrne PO. An audit of stereotactic and free hand biopsy. Br J Neurosurg 2002;16:411-2.
13. Westheimer G. Visual acuity. In: Hart WM, editor. Alder's Physiology of the Eye. St. Louis: Mosby Year Book; 1992. p. 538.