ORIGINAL ARTICLE

Quantitative and qualitative analysis of the working area obtained by endoscope and microscope in pterional and orbitozigomatic approach to the basilar artery bifurcation using computed tomography based frameless stereotaxy: A cadaver study

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ABSTRACT

Objective: Basilar aneurisms are one of the most complex and challenging pathologies for neurosurgeons to treat. Endoscopy is a recently rediscovered neurosurgical technique that could lend itself well to overcome some of the vascular visualization challenges associated with this pathology. The purpose of this study was to quantify and compare the basilar artery (BA) bifurcation (tip of the basilar) working area afforded by the microscope and the endoscope using different approaches and image guidance.

Materials and Methods: We performed a total of 9 dissections, including pterional (PT) and orbitozygomatic (OZ) approaches bilaterally in five whole, fresh cadaver heads. We used computed tomography based image guidance for intraoperative navigation as well as for quantitative measurements. We estimated the working area of the tip of the basilar, using both a rigid endoscope and an operating microscope. Operability was qualitatively assessed by the senior authors.

Results: In microscopic exposure, the OZ approach provided greater working area (160 ± 34.3 mm^2) compared to the PT approach (129.8 ± 37.6 mm^2) ($P > 0.05$). The working area in both PT and OZ approaches using 0° and 30° endoscopes was larger than the one available using the microscope alone ($P < 0.05$). In the PT approach, both 0° and 30° endoscopes provided a working area greater than a microscopic OZ approach ($P < 0.05$) and an area comparable to the OZ endoscopic approach ($P > 0.05$).

Conclusion: Integration of endoscope and microscope in both PT and OZ approaches can provide significantly greater surgical exposure of the BA bifurcation compared to that afforded by the conventional approaches alone.

Key words: Basilar artery, endoscope assisted microneurosurgery, endoscopy, frameless stereotaxy, orbitozygomatic approach, pterional approach

Introduction

Basilar aneurisms are one of the most complex and challenging neurosurgical pathologies. Even though the development of endovascular treatment has reduced the frequency of surgically treated basilar aneurisms,[1] neurosurgeons should maintain and improve their skills for approaching and dealing with these lesions. In fact, basilar aneurysms not amenable to endovascular treatment are usually among the most challenging ones to operate on. In this context, the use of endoscopes could be of value in allowing vascular visualization in a deep to reach, crowded and vital area. Indeed endoscopes produce exquisite close-up, and multi angled views.[2-6] Although endoscope systems are improving, the 2D image and the restricted working space are often limiting factors for the surgeon. On the other hand, three dimensional microscopic views along with better control of neurovascular structures make the microscope a crucial part of each micro-neurosurgical vascular procedure. Provided that the microscope offers excellent three-dimensional visualization and comfortable surgical access, and that the endoscope permits a wider and

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closer view of the target, integration of these two modalities should provide the greatest advantage in approaching this pathology.

There are different approaches to the basilar artery (BA) bifurcation,[7-12] and choosing among them depends mainly on the level of basilar bifurcation vis-à-vis the location of the dorsum sellae. Drake originally approached these aneurysms via a subtemporal route.[13] The disadvantage of this approach is the difficulty to expose the talamoperforating arteries if they arise as a single trunk from the P1 segment opposite to the craniotomy side as well as the need for temporal lobe retraction with its possible complications.[12] Yasargil in 1976 described the pterional (PT) route to approach the basilar tip.[14] It reduces both the need for temporal lobe retraction as well as the possibility of damaging the oculomotor nerve. Spetzler *et al*. advocated the orbitozygomatic (OZ) approach to the basilar tip.[7]

Purpose of the study

To evaluate and quantify the working area afforded by the endoscope and microscope to the BA bifurcation when performing PT and OZ approaches using image guidance.

Materials and Methods

Materials

Five fresh cadaver heads with color-injected arterial and venous systems were used in the study.

Methods

Computed tomography scans were performed on the cadaver heads, after implanting 4 micro screws around the planned craniotomy site, (slice thickness, 0,6 mm, contiguous non-overlapping slices; gantry setting, 0 degrees; scan window diameter, 225 mm; pixel size >0.44 × 0.44).

The Stryker navigation system (Kalamazoo, MI USA) was used for intraoperative guidance. Further details of the methodology used can be found in a previous publication.[15]

Endoscope and microscope

Microanatomic dissections were performed at × 3 to × 40 optical magnifications under a PENTERO operating microscope (Zeiss, Oberkochen, Germany). Endoscopic dissections were done with a rigid Stryker endoscope (Kalmazoo, MI, USA) 4 mm and 2.7 mm in diameter and 18 cm in length, with 0° and 30° lenses. The endoscope was connected to a light source via a fiber-optic cable and to a camera fitted with three charge coupling device (CCD) sensors. The video camera was connected to a 21 inch monitor that supports the high resolution of the three CCD technology as well as to the Pentero microscope in order to obtain a suitable file of anatomic images.

Surgical procedure

Two consecutive approaches were performed from the least to the most extensive. The first dissection was the PT craniotomy. The cadaver head was rotated 45° towards the opposite side of craniotomy and extended so that the zygomatic arch became the highest point. An arcuate scalp incision was started at the base of the zygomatic arch, 0.5 cm anterior of the tragus, and was extended to the opposite midpupilary line.[14] Next, an OZ craniotomy was performed by removing the orbital rim and zygomatic arch.[16]

Description of approaches

Pterional craniotomy

An arcuate scalp incision was started at the base of the zygomatic arch (0.5 cm anterior of the tragus) and was extended to the opposite midpupilary line. A muscle fascial preparation was fashioned such that a strip of myofascial cuff was left at the linea temporalis. The temporal musculature was reflected and retracted in the postero-basal direction in order to expose the pterion. A bone flap was sawed out using three burr holes, one at the key hole at the proximal part of the linea temporalis, one frontomedially on the squama frontalis and one on the sutura squamosa. This allowed the Sylvian fissure and the superior temporal gyrus to be exposed enough for further dissection. The sphenoid ridge was drilled away until the most lateral corner of the superior orbital fissure came into view. The dura was then incised in a curved fashion.[17,14]

Orbitozygomatic craniotomy

As the last stage, the orbital rim and the zygomatic arch were removed in one piece. The medial border was the orbital notch.[16]

Measurements

Cadaver heads were registered and an estimated registration accuracy of 1.0 mm on the navigation system was established.[15]

To ensure the validity of the quantitative assessment, brain retraction was held constant during each approach.

Working area

The working area was defined as the areas visualized at surgery and in which we could perform surgical maneuvers.

In order to calculate the working area, a trapezoid was delineated in the region of the BA using four anatomical landmarks. The four points selected were: (1) The junction of the ipsilateral internal carotid artery with the posterior communicating artery, (2) the most lateral point exposed on the ipsilateral posterior cerebral artery, (3) the lowest point exposed on the basilar trunk, (4) the most lateral point exposed on the contralateral posterior cerebral artery.

Clearly, while points 2, 3 and 4 varied between the endoscopic and the microscopic exposure, point 1 was kept constant during all the measurements. With the aid of the operating microscope, the researcher positioned the tip of a digitizing probe at each landmark while keeping the probe in view of the camera.

This allowed the navigation to determine the exact location of the landmarks by giving us the coordinates in the x, y and z planes.

We used the formula $\sqrt{[(X1-X2)^2 + (Y1-Y2)^2 + (Z1-Z2)]^2}$ to calculate the distance between each landmark, and then used the distances to calculate the area of the trapezoid.

In the next step, measurements were taken using the Stryker operating endoscope, with the probe positioned at all landmarks under 0° and 30° endoscope visualization (2 different angles).

Again during both sets of measurements (endoscopic and microscopic) point 1, the junction of posterior communicating artery with Internal Carotid Artery, remained constant [Figure 1].

The ability to operate on the exposed area was graded qualitatively by the 5 senior authors based on the ability to execute surgical maneuvers on the visualized area using both the microscopic and the endoscopic image. Surgical maneuvers performed included dissection of the perforators of the BA as well as of the other vascular structures exposed.

Statistical analysis

The statistical program SPSS 16.0 was used to evaluate our results.

Table 1: Surgical working areas in mm²

Dissection#	PT-M	PT-0	PT-30	OZ-M	OZ-0	OZ-30
1	81.74	152.62	166.26	116.84	150.34	196.62
2	115.41	218.25	240	195.6	261.45	280.93
3	81	111.23	130.57	124.02	249.3	426.97
4	165.2	219.2	270.56	124.36	259.33	308
5	130.28	220.01	250.6	160.2	240	311.4
6	136.3	263.9	330.2	188.1	268.4	359.5
7	194.1	252	272	214.2	241.4	251.6
8	110.2	236.3	257.4	156.1	182	213.1
9	154.8	283.1	345.7	160.8	272.2	311.4

PT – Pterional; OZ – Orbitozygomatic

Results

In all of our specimens, the basilar bifurcation was above the posterior clinoid, which made them suitable for the transsylvian approaches evaluated.

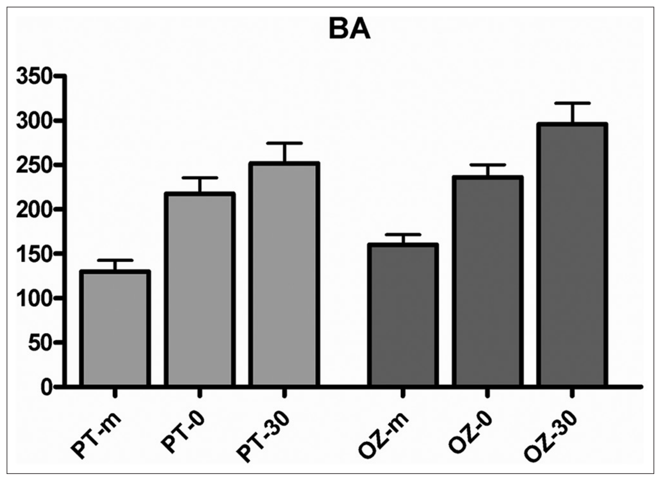
Table 1 shows the mean working areas obtained via the microscope and the endoscope in all our dissections.

Table 2 shows statistical evaluations of the working areas.

Graph 1 shows the comparison of the working areas obtained by microscope and endoscope in all approaches.

In microscopic exposure, the OZ approach provided greater working area (160 ± 34.3 mm²) compared to the PT approach (129.8 ± 37.6 mm²). This difference however, was not statistically significant ($P > 0.05$).

The exposed area in the PT approach using the 0° and 30° endoscope was significantly better than using the microscope (217.4 ± 54 mm² $P < 0.005$, and 251.4 ± 68.8 mm² $P < 0.005$ for the 0° and 30° respectively). There was also a significant difference between the endoscopic and microscopic



Graph 1: Graphic presentation of exposed areas

Table 2: Paired differences between approaches

Pair	Surgical approaches	Mean	Standard deviation	Standard error mean	95% Confidence interval of the difference: Lower	95% Confidence interval of the difference: Upper	t	df	Sig. (2-tailed)
1	PTM-PT0	−87.50889	36.32731	12.10910	−115.43253	−59.58525	−7.227	8	0.000
2	PTM-PT30	−121.58444	49.28538	16.42846	−159.46854	−83.70035	−7.401	8	0.000
3	PT0-PT30	−34.07556	20.35962	6.78654	−49.72535	−18.42576	−5.021	8	0.001
4	OZM-OZ0	−76.02222	41.82222	13.94074	−108.16963	−43.87482	−5.453	8	0.001
5	OZM-OZ30	−135.47778	81.79844	27.26615	−198.35362	−72.60193	−4.969	8	0.001
6	OZ0-OZ30	−59.45556	50.80243	16.93414	−98.50576	−20.40535	−3.511	8	0.008
7	PTM-OZM	−30.13222	33.79124	11.26375	−56.10647	−4.15798	−2.675	8	0.028
8	PT0-OZM	57.37667	41.02400	13.67467	25.84283	88.91051	4.196	8	0.003
9	PT30-OZM	91.45222	57.78686	19.26229	47.03331	135.87113	4.748	8	0.001

PT – Pterional; OZ – Orbitozygomatic; M – Working area working areas in the OZ approach; both 0° and 30° endoscopic working areas compared to the microscopic area achieved $P < 0.05$. In the PT approach, both 0° and 30° endoscopes provided a working area greater than a conventional microscopic OZ approach ($P < 0.05$) and an area comparable to the OZ endoscopic exposure ($P > 0.05$) [Graph 1].

Qualitative assessment showed that the lateral walls of the distal BA and its perforators were better visualized with the help of the endoscope in all the approaches studied. Moreover, the proximal BA was equally better visualized, in all approaches, using the straight and the angled endoscope. Evaluation of the ability to operate showed that the combined use of the microscope and of the endoscope created the most controlled environment in which to perform surgical maneuvers. This was true even in areas that were only visualized and that could only be operated on using the endoscope due to the ability of controlling, through the microscope, the entry and the position of the endoscope in the surgical field as well as to the ability of using the microscope linked 3-D information and depth perception. We found image guidance helpful in documentation of the exposure as well as in correlating to know anatomical landmarks the endoscopic ally acquired images.

Discussion

Basilar artery bifurcation

The complex anatomy of the tip of the BA region, with its anatomic variations and its multiple and very important perforators, in conjunction with the deep, hard to access location, poses challenging anatomic problems in the surgical treatment of aneurysms in this region.

Both vertebral arteries create the basilar trunk at the pontomedullary sulcus. The BA ascends ventral to the pons, behind the clivus, until it ends in the interpeduncular cistern. Hence the region of the basilar tip contains not only the terminus of the BA but also the bilateral P1 segments, an abundance of brain stems and diencephalic perforators coming from the BA itself or from the P1 segments as well as both third nerves. All this neurovascular anatomy is crowded in the interpeduncular fossa area,[7,18] making surgery of BA tip aneurysm extremely challenging.

Surgical approaches

One of the most commonly used approaches for treating these aneurysms is the PT approach.[17,14] It is often combined with an OZ approach.[16] It provides wide, multidirectional access to the anterior and middle cranial fossae. Removal of the OZ bar increases the angles of exposure, decreases the working depth of the surgical field, and minimizes brain retraction.

In these approaches, the internal carotid artery is in the middle of the field and obstructs a direct view of the BA. Three surgical corridors to the BA are available: the opticocarotid space, the medial retrocarotid space and the lateral retrocarotid space.[17] The opticocarotid triangle is usable if it is sufficiently large, as occurs when both the internal carotid artery and the anterior cerebral artery are long, but it is inadequate if these arteries are short and the ICA runs tightly beside the optic nerve and the chiasm[18] [Figures 2-4].

Endoscope assisted microneurosurgery

While the endoscope had been occasionally used in neurosurgical procedures since the beginning of the 20th century, it was Jho in 1993 who reintroduced the endoscope to neurosurgery on a wide scale to remove a pituitary tumor through the sphenoid sinus.[19] Kassam *et al*. have since further popularized transsphenoidal endoscopic neurosurgical approaches to the skull base.[20] Endoscope assisted microneurosurgery was proposed by Perneczky, among others, in the 90s, mainly to address vascular pathology using minimally invasive craniotomies.[2] The disadvantage of the narrow corridors afforded by the small craniotomies was compensated by the ability of the endoscope to provide additional information on the surgical field.[2] Sekhar reported on the use of the endoscope in an assisted manner to microsurgery in patients with cerebral aneurisms and microvascular compression syndromes.[3,6]

Present study

Our study was undertaken to verify the hypothesis that integration of the endoscope and the operating microscope could afford better visualization of the BA bifurcation than any technique alone.

In fact, for any given approach, by and large, the endoscope provides better lighting and exposure than the microscope. However, the endoscope, at least in the present commercially available iterations, does not provide 3-D view and hence depth perception. Moreover, the microscope provides the surgeon with control of the whole surgical field, compared to only distal (at the endoscope tip) control afforded by the endoscope.

Integration of the endoscope and microscope (endoscopic-assisted microneurosurgery) could result in combined advantages. Indeed, the endoscope could expose and visualize structures that are inadequately exposed or not exposed at all due to the straight line of view obtained by the microscope.

Consequently, we reasoned that we could preserve the proven advantages of microscopic neurosurgical techniques while the introduction of the endoscope could provide additional visualization of the surgical field, which is limited by the narrow corridor in the microscopic view due to the deep location of the BA.

Our results show that, in our model, endoscopic assisted microsurgery is associated with a wider working area than microsurgery alone. Indeed we showed that using 0° and 30° endoscopes via a PT craniotomy we achieved better exposure that using the microscope via an OZ craniotomy (217.4 ± 54 mm^2, 251.4 ± 68.8 mm^2 and

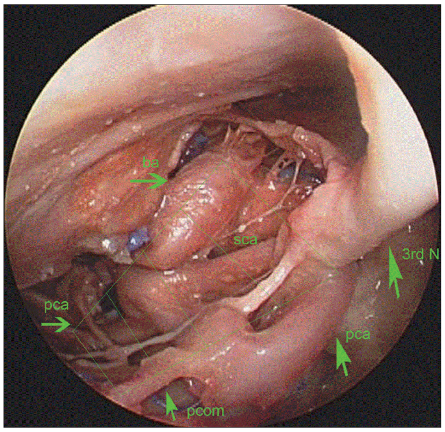


Figure 1: Trapezoid delineated on anatomical landmarks (BA-basilar artery, SCA-superior cerebellar artery, P1-P1 segment of posterior cerebral artery, P2-P2 segment of posterior cerebral artery, PCOM-posterior communicating artery, N3-oculomotor nerve)

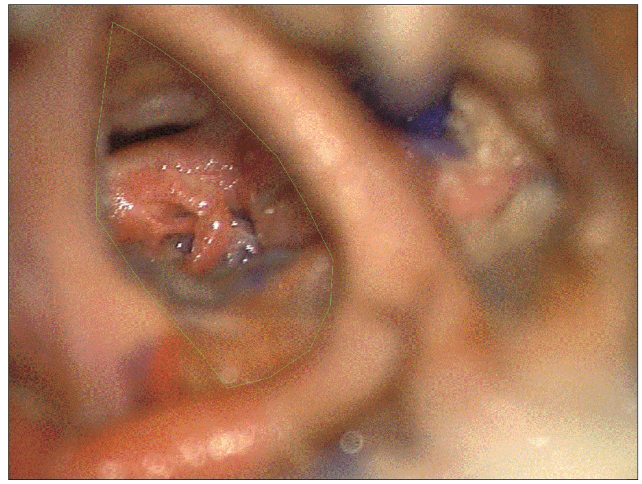


Figure 2: Pterional approach. Microscopic view of the basilar tip (arrow) through the opticocarotid space

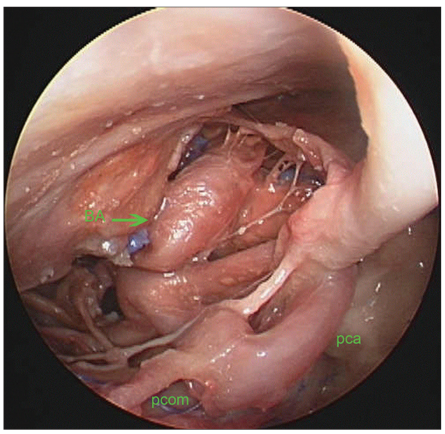


Figure 3: Pterional approach. Endoscopic view of tortuous basilar bifurcation as seen through the retrocarotid space. The arrow is pointing the basilar tip (BA-basilar artery, SCA-superior cerebellar artery, P1-P1 segment of posterior cerebral artery, P2-P2 segment of posterior cerebral artery, PCOM-posterior communicating artery, N3-oculomotor nerve)

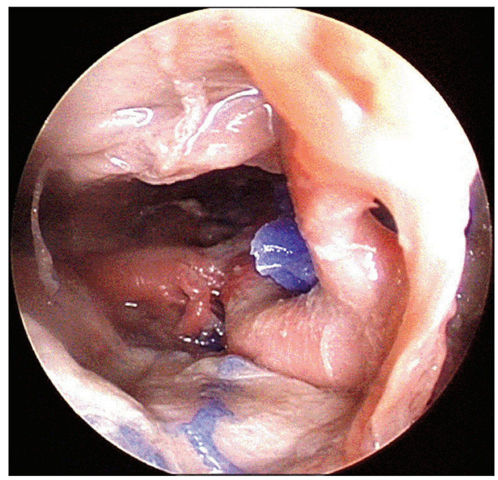


Figure 4: Pterional approach. Endoscopic view of basilar artery bifurcation as seen through the opticocarotid space. The arrow is pointing the basilar tip (P1-P1 segment of posterior cerebral artery, PCOM-posterior communicating artery)

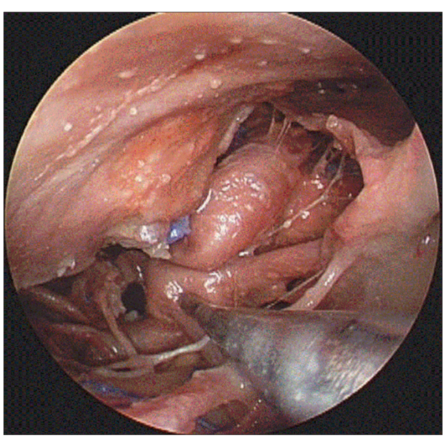


Figure 5: Pterional approach. Navigation pointer on the basilar artery (BA) tip, visualized with an endoscope. A large segment of the BA trunk is visible. (BA-basilar artery, SCA-superior cerebellar artery, P1-P1 segment of posterior cerebral artery, PCOM-posterior communicating artery, N3-oculomotor nerve)

160 ± 34.3 mm^2 respectively). This difference was statistically significant ($P < 0.003$ and $P < 0.001$ respectively).

Even though our specimen had a high BA bifurcation, using the endoscopes, we could expose a significant length of the proximal, retrosellar and retro clival, BA. In addition we could execute surgical maneuvers well at the middle of the BA [Figures 5-7].

Likewise, one must be cogniscent that, with the present status of technical development, it is very arduous to operate on structures visualized with the angled endoscopes. Visualization does not necessarily mean safe operability. Moreover, by integrating the microscope and the endoscope the surgeon is able to continuously utilize and integrate the information garnered through one or the other tool, thereby optimizing the end result. Indeed the 3-D perception associated with the microscope may be transmitted to the endoscopic part of the

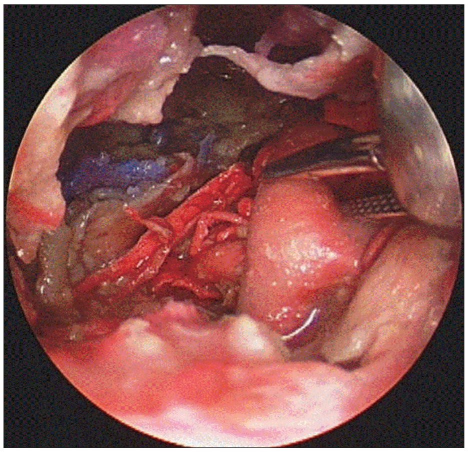


Figure 6: Pterional approach. Manipulation (aneurismal clip placement) over the basilar artery trunk which can be exposed only by endoscope. The arrow is indicating the basilar tip

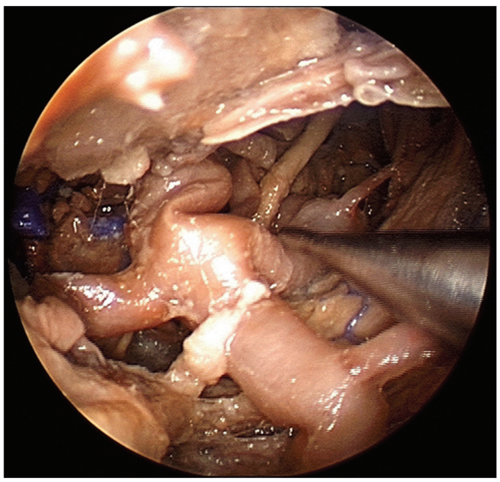


Figure 7: Pterional approach. Navigation pointer on the mid basilar artery. Bifurcation nicely visible

operation and the endoscopic ability to look around the corner may be transferred to the microscope part of the operation.

Clearly, the ability to look around the corners and to know where vascular structures are located is crucial when operating on BA vascular lesions.

Conclusion

In our model, the combined use of endoscopes and microscope is associated with exposure of structures that are not visualized by using the operating microscope alone. In our study, endoscopic working areas in the PT and OZ approaches were significantly larger than the exposed area of the BA complex afforded by conventional microscopic approaches. Furthermore, integration of the endoscope and the microscope afforded the best conditions for the safest execution of surgical maneuvers.

Furthermore, the use of image guidance systems during endoscopic procedures gives the surgeon a constant orientation in the surgical field, thus increasing the accuracy and the safety of the approach.

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