ORIGINAL ARTICLE

Computed tomography–guided aspiration versus key-hole craniotomy for spontaneous putaminal haemorrhage: a prospective comparison of minimally invasive procedures

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Objectives To compare the effectiveness of two minimally invasive procedures, namely computed tomography–guided aspiration and the key-hole approach, in the neurosurgical management for spontaneous putaminal haemorrhage, and to explore the indications for the two approaches.

Design A multicentre, single-blinded controlled trial.

Setting Hospitals taking part in this trial and the sources for patients were from China. Among others, the hospitals involved in the interventions included: the Beijing Tiantan Hospital (of the Capital University of Medical Sciences), the General Hospital of People's Liberation Army, the Peking Union Hospital, and the Shanghai Huashan Hospital (of the Fudan University medical school).

Patients From September 2001 to November 2003, data were available for analysis from a total of 841 patients with spontaneous putaminal haemorrhage from 135 hospitals all over China (except Tibet, Hong Kong, Taiwan, and Macao). All follow-up data were for at least 3 months.

Main outcome measures Mortality, Glasgow Coma Scale score, postoperative complications, Kanofsky Performance Scale score, and Barthel Index.

Results There were 563 patients who underwent computed tomography–guided aspiration, and 165 were treated by the key-hole approach. Respective mortality rates 1 month after the operation were 17.9% and 18.3%; at 3 months they were 19.4% and 19.4%. In those undergoing computed tomography–guided aspiration, mortality rates at 3 months after the operation were 28.2% in patients with Glasgow Coma Scale scores of 8 or below, as opposed to 8.2% in those with higher scores. This amounted to a 3.4-fold difference. In those treated by the key-hole approach, the corresponding rates were 30.2% and 7.6%, which amounted to a 4-fold difference. The corresponding mortality at 3 months in patients with complications was 3.9 times as great as in those without complications. In those with haematoma volumes of 70 mL or greater, it was 2.7 times as much as in those in whom the volumes below 30 mL. The postoperative complication rate of computed tomography–guided aspiration (23.7%) did not differ significantly from that in those having the key-hole approach (25.7%) [P=0.420].

Conclusions Computed tomography–guided aspiration is not superior to the key-hole approach for treating spontaneous putaminal haemorrhage in terms of favourable outcomes, mortality, and morbidity. However, it could be the first-choice approach for those with bleeds of 50 mL or less, while the key-hole approach may be more suitable for those with larger haematomas.

Key words
Hematoma; Intracranial hemorrhage, hypertensive; Neurosurgical procedures; Putaminal hemorrhage; Tomography, X-ray computed

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Introduction

In China, spontaneous intracerebral haemorrhage (ICH) is the pathology of 21 to 48% of patients having strokes. The mortality and disability of ICH rank first among all types of apoplexies, and the 1-month fatality rate ranges from 30 to 50%, and over 30% of survivors suffer decreased functionality. Spontaneous putaminal haemorrhage (SPH) accounts for about 10% of all strokes and is fatal in about 50% of affected patients.[1] Being a devastating type of stroke that mostly results in death or severe neurologic deficit, it demands long-term medical and social care, imposes heavy financial and emotional burdens on patients and their families, whilst also causes an enormous loss to society.

The purpose of surgical clearance of ICH is to alleviate compression by avoiding further enlargement of the haematoma, and inhibit the release of cytotoxic products, and by this means, lower the fatality and disability rates. Presently, minimally invasive surgical interventions entail the key-hole approach (KHA) as opposed to computed tomography–guided aspiration (CTGA). However, there has been no large-scale randomised clinical trial to explore the indications for either forms of surgical treatment for ICH.[2-4] Controversy about the value of surgical treatment for ICH also exists in China,[5,6] where no guidelines for such treatment have been established. Reviewing literatures in recent years, most authors recommended stereotactic aspiration by endoscope using the KHA, since SPH is a deep-seated haematoma.[7,8] It might therefore be worth conducting a study to determine whether localisation of the ICH matters.

Since neuro-endoscopy has not been widely used and available in China, we conducted this study in patients with SPH, in an attempt to evaluate the effectiveness and indications for the two different types of surgical intervention, CTGA and KHA.

Methods

This study was a multicentre, single-blinded controlled trial that covered 135 hospitals all over China (except Tibet, Hong Kong, Taiwan, and Macao). It was performed to analyse the influence of a series of variables present on admission, which included: age, Glasgow Coma Scale (GCS) score, operation mode, prior history of hypertension, haematoma volume, limb muscle strength, and other complications.

Clinical data

The investigators included neurosurgeons and others from Beijing Tiantan Hospital (medical school hospital of the Capital University of Medical Sciences), the General Hospital of People's Liberation Army, the Peking Union Hospital, and the Shanghai Huashan Hospital (medical school hospital of Fudan University). The patient data sets were transferred through the network of Surgical Treatment for Brain Stroke; surgeons were able to fill in a standardised table on the network, and there were specific personnel appointed to collect the data and feedback the information. The trial spanned from 1 September 2001 to 10 November 2003, when the 3-month follow-up for all patients was concluded. A total of 841 sets of patient data were thus available for analysis.

Inclusion and exclusion criteria

For putaminal haemorrhage revealed by computed tomographic (CT) scan within 72 hours of symptom onset, surgery was performed within 24 hours if necessary. Inclusion criteria were: GCS score of 5 or more, primary CT cerebral haemorrhage volume estimated to be 30 mL or more, patient age between 14 and 75 years, patient's/family's signed consent to participate in the study. Exclusion criteria were:

以電腦X光斷層掃描引導下抽吸術及鎖孔開顱術治理自發性殼核出血：兩種微創手術的預後研究

目的 比較兩種治理自發性殼核出血的腦外科微創手術：電腦X光斷層掃描引導下抽吸術及鎖孔開顱術，及探討它們的效用。

設計 多中心單盲對照試驗。

安排 所有參與本研究的醫院及病人均來自中國，包括：北京天壇醫院（首都醫科大學）、中國人民解放軍總醫院、北京協和醫院、上海華山醫院（復旦大學附屬教學醫院）。

患者 2001年9月至2003年11月期間，來自中國135間醫院共841名自發性殼核出血患者的數據（西藏、香港、台灣和澳門除外）。所有個案的隨訪期最少為3個月。

主要結果測量 死亡率、格拉斯哥昏迷指數、術後併發症、Karnofsky氏體能表現狀態和巴氏量表。

結果 563位病人接受電腦X光斷層掃描引導下抽吸術，另165位接受鎖孔開顱術。兩組的術後一個月死亡率分別為17.9%及18.3%；術後三個月死亡率則均為19.4%。接受抽吸術的患者當中，格拉斯哥昏迷指數為8或以下的術後三個月死亡率為28.2%，指數較高的則為8.2%，足有3.4倍的差異。接受鎖孔開顱術的病人，相對的死亡率為30.2%及7.6%，足有4倍差異。出現併發症患者的術後三個月死亡率，較沒有併發症的高3.9倍。血腫量有70 mL或以上的，較30 mL以下的高2.7倍。兩組的術後併發症率沒有顯著差異（P=0.420）：抽吸術組為23.7%，開顱術組則為25.7%。

結論 從死亡率和發病率來看，以電腦X光斷層掃描引導下抽吸術治理自發性殼核出血並不較鎖孔開顱術優勝。不過，對於血腫量為50 mL或以下的，抽吸術可能是首選治療方法，但對血腫量較多的病人，鎖孔開顱術則可能較為適合。

TABLE 1. Summary of clinical data in patients having the key-hole approach (KHA) and computed tomography–guided aspiration (CTGA)

Clinical characteristic*	KHA (n=165)	CTGA (n=563)
Mean (SD) age (years)	54.6 (8.9)	56.1 (9.0)
Hypertension history	76%	60%
Other complications		
Stroke	4%	5%
CHD	6%	5%
DM	3%	5%
Smoking/alcohol	41%	34%
GCS score		
On admission ≤8	49%	47%
Preoperative ≤8	52%	46%
Abnormal limbs muscle strength	58%	57%
Abnormal pupils	18%	15%

* SD denotes standard deviation, CHD coronary heart disease, DM diabetes mellitus, and GCS Glasgow Coma Scale

TABLE 2. Mortality in patients having the key-hole approach (KHA) and computed tomography–guided aspiration (CTGA)

Mortality	KHA (n=165)	CTGA (n=563)	P value
2 Weeks	15.4%	14.0%	0.885
1 Month	18.3%	17.9%	0.614
3 Months	19.4%	19.4%	0.666

haemorrhage resulting from cerebral aneurysm, arteriovenous malformation, cerebral trauma, tumour-causing stroke, brainstem haemorrhage, more than 24 hours had elapsed since presentation, and severe co-morbidity (significant renal, liver, or heart failure).

Operative method and grouping

The operative approach (CTGA or KHA) was selected by the surgeon, based on the patient's condition after consent was obtained. To ensure standardisation and a consistent surgical method, training courses were held to standardise the operations. For patients having CTGA, a bur hole was made according to the CT location of the haematoma. After aspirating most of the haematoma through the bur hole, a drain tube was left in situ for 3 to 5 days. The KHA was performed via microsurgery, with a bone flap of no more than 3 cm in diameter.

Outcome assessment

Outcome was assessed at 1 and 3 months following the SPH during follow-up examinations, using the Glasgow Outcome Scale (GOS) score. Outcomes were grouped as favourable (good recovery with independent living), or unfavourable (death, persistent vegetative state, or dependent living). All clinical data and outcomes were assessed without prior knowledge of the surgical approach.

Statistical analyses

The following specific statistical methods were included: χ^2 test for the group comparison of enumerated data, and analysis of variance for the group comparison of measurement data. Clinical effects following the two operative modes were compared, setting an α value of 0.05. In the multiple-factor regression analysis, a forward stepwise regression (0.05) fitting model was employed with survival or death during the 3-month follow-up as the end-point (dependent variable), and the GCS score, operative approach, hypertension history, haematoma volume, age, complications, and limb muscle strength on admission were treated as independent variables. The Statistical Package for the Social Sciences (Windows version 11.0; SPSS Inc, Chicago [IL], United States) was used for data analysis.

Results

Comparison of the clinical data

Of 841 patients, 728 were operated on; 563 having CTGA and 165 having KHA. Analysis of the baseline characteristics of the patients on admission showed that although those having the KHA had a higher proportion with hypertension, there was no statistically significant difference between the two groups (Table 1). Nor were there any statistically significant differences between the groups with respect to other co-morbidities, muscle strength on admission (P=0.069), as well as preoperative and admission GCS scores (P>0.05).

Comparison of bleeding volume and surgical results

The mean volume of the bleeds was 53 (standard deviation [SD], 22) mL in the CTGA group and 55 (SD, 19) mL in KHA group.

Table 2 summarises mortality at postoperative week 2, month 1, and month 3; the rates being 15.4%, 18.3%, and 19.4%, respectively in the KHA group, and 14.0%, 17.9%, and 19.4% in the CTGA group. Intergroup comparison indicated that there was no statistically significant difference in case fatality between them at the three different time-points.

In those undergoing computed tomography–guided aspiration, mortality rates at 3 months after the operation were 28.2% in patients with Glasgow Coma Scale scores of 8 or below, as opposed to 8.2% in those with higher scores. This amounted to a 3.4-fold difference. In those treated by the key-hole

TABLE 3. Favourable outcomes according to Glasgow Coma Scale (GCS) score in patients having the key-hole approach (KHA) and computed tomography–guided aspiration (CTGA)

Favourable outcome*	KHA (n=165)	CTGA (n=563)	P value
2 Weeks	31.4%	24.0%	0.099
1 Month	48.1%	36.8%	0.089
3 Months	68.8%	63.8%	0.074

* The favourable outcome refers to independent living (Glasgow Outcome Scale score: 4 or 5)

TABLE 4. Mean (±standard deviation) Kanofsky Performance Scale (KPS) and Barthel Index (BI) scores at 1 and 3 months after putaminal haemorrhage in patients having the key-hole approach (KHA) and computed tomography–guided aspiration (CTGA)

	1 Month after haemorrhage		3 Months after haemorrhage	
	KHA	CTGA	KHA	CTGA
KPS score	57.3±15.1	57.2±18.1	67.2±14.7	65.4±18.1
P value	>0.05		>0.05	
BI score	57.4±25.3	50.8±24.0	70.8±26.1	66.0±27.4
P value	>0.05		>0.05	

approach, the corresponding rates were 30.2% and 7.6%, which amounted to a 4-fold difference.

The postoperative complications included: recurrent intracranial haemorrhage, cerebral infarction, pulmonary embolism, cardiac infarction, and pneumonia. Multiple-factor regression analysis indicated that the 3-month mortality of patients with complications was 3.9 times of that of those without complications.

Although there was no statistically significant difference between the two groups with respect to the rate of postoperative complications (CTGA 23.7% vs KHA 25.7%, P=0.420), among patients with haematoma volumes of 50 mL or less, the complication rate in the KHA group was 30.3%, which was significantly higher than the value of 16.7% in the CTGA group. However, in patients with haematoma volumes exceeding 50 mL, the complication rate in the KHA group (20.9%) was lower than that in the CTGA group (32.9%); the difference being statistically significant. Thus, the CTGA approach could be the first choice for patients with haematoma volumes of 50 mL or less, while the KHA could be the first choice for those with larger haematomas.

Patient outcomes were assessed by GCS, Kanofsky Performance Scale (KPS), and Barthel Index (BI) scores at 1 and 3 months after the surgery. Analyses showed that there was no statistically significant difference between the KHA and the CTGA groups (Tables 3 and 4), and no particular index showed up which of the two operative approaches was superior.

Multiple-factor prognostic correlation analysis

A multivariate logistic analysis by forward stepwise regression was used to extend the model with six variances (GCS scores on hospitalisation, haematoma volume, age, level of consciousness, complications after operation, and all extremity movements and muscle strength).

According to the analysis, a preoperative GCS score of 8 or below yielded a 2.6-fold greater risk of death at 3 months than if the scores exceeded 8. At 3 months, the mortality rate of patients with a postoperative complication was 3.9 fold that of those with no complications. The 3-month mortality of patients with preoperative abnormality of extremity movement and/or muscle strength was 1.6 fold that of patients without such abnormalities. When the haematoma volume was 70 mL or greater, the 3-month mortality increased to 2.7 fold that of patients with bleeds smaller than 30 mL. Patients with a history of hypertension had lower BI scores 1 month after the operation. The KPS and BI scores decreased with increasing patient age.

Discussion

Intracerebral haemorrhage (cerebral apoplexy) is generally affected by environmental and inherited factors. Blood pressure, diet (eg high salt intake), hypertension, hyperglycaemia, age, and smoking increase the risk of ICH.[9-13] In the present study, a majority of patients (66%) were aged 50 to 70 years. Most (68%) had hypertension together with a history of either smoking or excessive alcohol intake. In the present study, no familial factors were found to be involved.

The present study revealed that haemorrhage volume was one of the factors affecting patient survival; other factors included haemorrhage location, stroke history, the GCS score on admission (with or without an intraventricular haematoma), and complications. Although some patients benefited from surgical intervention, we could not draw a clear conclusion since they were not randomised to particular treatments, and there were multiple factors affecting outcomes. We believe it may be better to conduct a randomised controlled study, stratifying the patients according to the location of their bleed.

At present, ICH is classified into six types (cortex [lobe], putamen, caudate nucleus, thalamus, cerebellar, and multifocal) based on the location of the haematoma. Putaminal haemorrhage is the most devastating, and mostly results in death or severe neurological deficit. Hence it was the focus of this study.

The mean hemorrhage volume was 53 (SD, 22) mL in those having CTGA and 55 (SD, 19) mL in the

KHA group, which were therefore quite similar. This suggests that haemorrhage volume had no bearing on surgical procedure selection.

Previous study[14] have shown better haematoma clearance within 12 hours of ICH if surgical intervention occurred within 4 hours. Nevertheless, Morgenstern et al[15] found that if surgical clearance of haemorrhage occurred within 4 hours it was hard to stop the bleeding and the patients were prone to re-haemorrhage. All the patients admitted into present study underwent operation within 24 hours and the results indicated no significant differences in 1-month mortality between the two groups, implying that the surgical approach did not matter for operations carried out within 24 hours of ICH.

The generally accepted types of surgery include: simple aspiration, conventional craniotomy, and minimally invasive clearance. For ICH in the early phase of cerebral herniation, most researchers consider conventional craniotomy has an advantage in clearing the haematoma, whilst the bone flap craniotomy or subtemporal decompression benefits some patients.[13,16] It is also believed that the favourable outcomes of minimally invasive surgery can be improved by additional procedures (drainage of haematoma, aspiration through an ossicle or pyramidal trephining of the skull), or by the application of a haematoma liquefier such as recombinant tissue plasminogen activator, streptokinase, and low-molecular heparin. These methods can improve the level of consciousness of patients with deep-seated haematomas, and assist their earlier rehabilitation while avoiding complications.[17-19]

The present study mostly used the CTGA or KH approaches to surgery for patients of putamen bleed. There are many factors influencing surgery selection, including: haemorrhage volume, general status on admission, the GCS score, the doctor's experience and skill, having to undertake other surgery, availability of local surgical equipment, as well as patient/family inclinations and economic circumstances.

Comparison of the prognosis and outcomes in the two groups (based on BI and complications) revealed no significant differences; no indices showed one kind of operation to be superior. Therefore, further analysis with longer follow-up is necessary.

For all patients, the most important predictors of 3-month mortality were: the preoperative GCS score, postoperative complications, and preoperative limb muscle strength. Haematoma volume affected 3-month mortality only when it was 70 mL or greater.

In the KHA group, only the GCS score had a strong correlation with 3-month mortality. While in the CTGA group, both GCS score and postoperative complications correlated strongly with 3-month mortality, and only bleed volumes of 70 mL or greater had a significant impact on the 3-month mortality. Thus, with respect to the 3-month mortality, preventing postoperative complications is the key to the surgical treatment of putaminal haemorrhage.

The present results also suggest that CTGA could benefit patients by reducing postoperative complications and enhancing favourable outcomes in patients with haematoma volumes of 50 mL or less, while the KHA offers more benefit to those with bleed volumes of more than 50 mL. Intracerebral haemorrhage volume is probably more important than GCS score in determining treatment. Our experience is also consistent with a new retrospective study.[8]

Conventionally, the prognosis correlated strongly with the level of consciousness; a GCS score of 8 or lower led to a poor prognosis in over 95% of the patients. The study of Phan et al[20] revealed that for deep-seated ICH, such as in the putamen, haemorrhage volume on admission, and a GCS score under 8 were both apparently correlated with 30-day mortality. This study showed that the mortality of patients with GCS scores of 8 or below was 3.4 times that of patients who scored higher, which also confirms the conventional view.

Our study revealed that 68% of patients also had hypertension, and to a lesser degree a history of smoking/alcohol abuse. Thus, monitoring of blood pressure, education and promotion of healthy lifestyles could have a major impact on reducing the incidence of stroke.[21] Long-term control of hypertension is necessary to avoid relapse of haemorrhages.[22] Public knowledge of stroke should be promoted, in order to reduce the risks and accelerate access to medical care.[23]

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