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Perspective

Endoscopic treatment of hypertensive intracerebral hemorrhage: A technical review

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Abstract

Hypertensive intracerebral hemorrhage (ICH) is still a highlighting global issue. Endoscopic evacuation as a minimally invasive treatment became an alternative other than conventional craniotomy and catheter drainage for ICH. However, there is no unified indication or standardized procedure on endoscopic treatment of ICH. Here we explored the literature and gathered information from different studies, to review the background, technical points, and existing problems of endoscopic treatment for ICH.

Keywords: Endoscopic treatment; Hypertension; Intracerebral hemorrhage (ICH); Hematoma evacuation

Introduction

Intracerebral hemorrhage, formerly referred to as "hypertensive hemorrhage", is the second most common (31.5%), but the most deadly (51.7%) form of stroke throughout the world.[1] Recent findings have estimated that the absolute number of people with incident hemorrhagic stroke increased significantly by 47%, yet reduction in the mortality, in disability-adjusted life-years (DALYs), and in mortality-to-incidence ratios rates, which possibly related with medical improvements and global population expansion.[1,2] Although the rates statistically reduced, the median 30-day mortality following ICH is still approximately 40%, and the 1-year mortality is up to 64%.[3] Moreover, among the population who suffered from ICH, only 20% of the patients can survive independently at 6 months, which indicates the importance.[4] However, the cost of survivors for hospitalization together with the first year post-discharge therapy can reach more than 44,000 dollars,[5] which is a great economic burden, especially for low-income countries.

The most important risk factor for ICH is hypertension.[6–8] A meta-analysis showed that blood

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pressure of >160/90 mmHg increased the risk of intracerebral hemorrhage more than ninefold.[8] Smoking and drinking are also compelling evidence for intracerebral hemorrhage.[8] Medication such as warfarin and aspirin can also contribute to ICH, although their benefits far outweigh the potential risks.[9,10] Moreover, the incidence of ICH was 15% lower in women than men, though not statistically significant.[6] Age and hypertension are main etiologic factors. Hypertensive hemorrhages are the most common cause of ICH in patients aged 45−70 years and are more likely to be located in the deep brain structures such as the putamen (60−65% of cases), thalamus (15−25%) and pons/cerebellum (10%).[11] In patients <45 years old, the most important etiology is underlying vascular lesions such as arteriovenous malformations, cavernomas or aneurysms.[12]

General management of ICH contains medical and surgical treatment. Population-based studies show that most patients present with small ICHs that are readily survivable with good medical care. Patients with cerebellar hemorrhage who are deteriorating neurologically or who have brainstem compression and/or hydrocephalus from ventricular obstruction should undergo surgical removal of the hemorrhage as soon as possible (Class I; Level of Evidence B).[13] However, the role of surgery for most patients with spontaneous ICH remains controversial. When there is uncertainty of preferred treatment present, International Surgical Trial in Intracerebral Hemorrhage (STICH) and minimally invasive surgery (MIS) treatment for the patients with spontaneous supratentorial intracerebral hemorrhage (MISTICH) can be a reference.[14,15] STICH showed early surgery in patients with spontaneous supratentorial intracerebral hematomas has a 2.3% absolute benefit (95% *CI*: 3.2−7.7) and 10% (95% *CI*: 13−33) relative benefit over initial conservative treatment, but no overall benefit.[14,16] In the following STICH II states that early surgery has a small but clinically relevant survival advantage for patient with spontaneous superficial intracerebral hemorrhage without intraventricular hemorrhage.[17]

Surgical intervention for ICH mainly consists of three general methods, conventional craniotomy, endoscopic treatment, and catheter drainage. The gist in surgical intervention for ICH is to remove clot, to relief mass effect, and to reduce cytotoxic and perihematoma edema.[18−21] With the development of medical instrument and the deeply rooted "Minimal invasive" concept, endoscopic hemorrhage evacuation for treating hypertensive ICH is becoming more and more popular.

The first controlled randomized study about Endoscopic surgery versus medical treatment for spontaneous intracerebral hematoma was reported by Ludwig M. Auer, et al. in 1989.[22] The study demonstrates a significantly lower mortality rate (30%) than the medically treated group (70%, $P < 0.05$) for subcortical hematomas. However the outcome of surgical patients with putaminal or thalamic hemorrhage was no better, but the trend to become better quality of survival and chance of survival in the operated group.[22] Later studies showed a same to higher evacuation rate from 79.2% to 99% with significant compared with craniotomy.[23−26] Complications were more frequent in the craniotomy group. There was no difference in the occurrence of other complications, including revision surgery digestive tract ulcer and epilepsy. Proportion of patients with good prognosis (ADL I−III) was larger in the keyhole group ($P < 0.05$). The mean change in Glasgow Coma Scale (GCS) score was +4.8 for the endoscopy group and −0.1 for the craniotomy group ($P < 0.001$).[24]

The general procedure of endoscopic clot evacuation including creation of a linear skin incision (3−4 cm) and a 1−2.5 cm bur hole or a small craniotomy is then created with dura opened in "Z" shape. A stylet or introducer was inserted into through preoperative designed approach to favorable depth. Along the stylet or introducer, genteelly cannulate with a sheath through normal brain tissue to the hemorrhage with calculated depth. Under endoscopic direct visualization, mainly using suction to remove the hematoma. After satisfied intra-operative hemostasis and irrigation, placing coagulate and gradually retracting the sheath from deep to surface to clear up the hematoma cavity. With or without drainage, close the patient up in standard process.

Pre-operatively, neuroimaging is mandatory. Computed tomography (CT) and magnetic resonance imaging (MRI) are both reasonable for initial evaluation. Moreover, neuroimaging can be later used for surgical planning and navigation. Blood pressure should be maintained under 140 mmHg of systolic blood pressure (SBP),[13,28,29] avoiding using nitroglycerin which may increase ICP. Decompression craniotomy should be performed for consistent high ICP post-operatively. Patients with catheter after surgery can accept further treatment through the drainage, if hematoma residual was found by postoperative CT.[20] A study showed minimally-invasive surgery plus recombinant tissue plasminogen activator (rtPA) for intracerebral hemorrhage evacuation has tentative grater clot resolution than traditional medical management.[30]

Crucial technique points and options for endoscopic evacuation of ICH

Instruments for endoscopic evacuation of ICH

Endoscopes that can serve the duty for illumination and close visualization are encouraged to use, either rigid or flexible endoscope, with or without irrigation system. 0° is more popular than 30° endoscope for clot removal. For the manipulation with endoscope and suction, an approaching passage is required. Earlier, evacuation was carried out through endoscopic troca or customized syringe.[31] In the recent 20 years, more available sheathes were designed to reduce damage to normal brain tissue along the cannulation, and provide with further advantages, such as stainless steel sheath,[32] NeuroPort,[33,34] ViewSite,[35] and other expandable cannula system (Fig. 1).[36–38] The sheath can be secured with holders[26] or used in a flexible style.[39] Moreover, other equipment and customized instruments are gradually introduced to facilitate this surgery.[40]

Approaches to the hematoma

Approaches are carefully designed according to the location of hematoma. For hematoma in basal ganglia, 2–3 cm anterior to coronal suture and 3–4 cm lateral to the midline is preferred as the entry point. For thalamic hematoma, a parietal entry point is preferred. For subcostal hematoma, a shortest approach is preferred.[26] The endoscope is commonly through the approach and inserted to two-thirds of the hemorrhage along the axis.[41] Other approaches, such as frontal bur hole[42] and Keyhole[43,44] approach are also in consideration to surgeons preference. Recently, a dual-channel[45] approach was reported for a better visualization with endoscope, however, would cause substantial damage compared to the others.

Methods for evacuation and hemostasis[27]

In order to avoid damaging the brain parenchyma with excessive manipulation of the sheath, hematoma was removed from the most distal part and as the sheath is gradually withdrawn the residual hematoma will be pushed into the tip of the sheath as the brain expands. The hematoma is evacuated by manipulating the suction through the working space within the sheath. About 70% of ICHs could be evacuated without an obvious or active bleeder being identified intra-operatively.[27] Another theoretically method to remove the hematoma is described by Nagasaka *et al.* as the inflation–deflation.[46] A clot that is adhesive to the hemotoma cavity should not be sucted with force. Instead, rolling the clot gently with snowball motion to free it with surrounding malacotic brain tissue, then remove it with forceps.

Most bleeding from these perforators stopped after gentle compression with cotton and irrigation for 2 min, which is described as wait-and-see saline irrigation. When bleeder is identified with an endoscope, coagulation would be preferred. With the endoscope held by an assistant or robotic arm, the bleeder can be ideally coagulated with bimanual manipulation with bipolar and suction. Another way is the surgeon holding the endoscope in one hand and the other hand gentlely retracting the bleeder with suction, letting the assistant to coagulate the bleeder by touching the

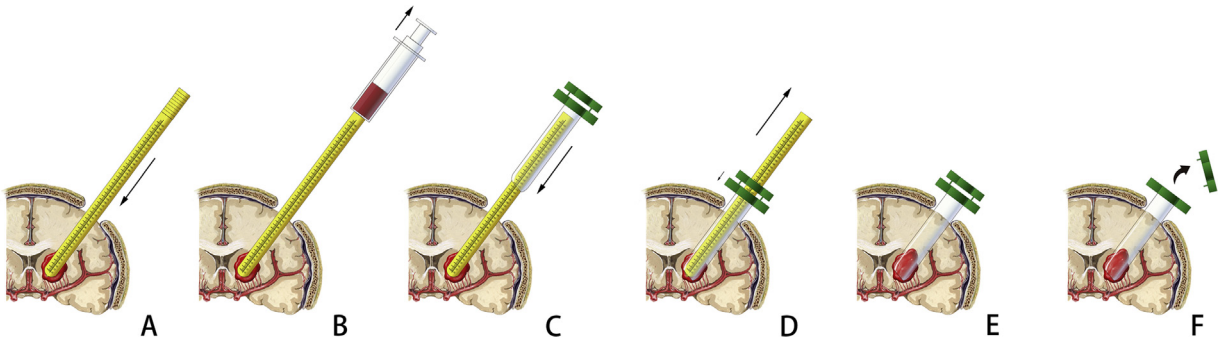

Fig. 1. Schematic diagram showing the use of a new endoscopic port system which we developed (VDY20115, Jingcheng Medical Instruments, Shanghai, China). **A.** After dura opening, an introducer was inserted into hematoma with preoperative design; **B.** Remove the pith inside the introducer and draw blood through the introducer with a syringe to make sure it is inside the hematoma (Some systems may skip this step); **C.** Insert the working port along the introducer and further dilate the trajectory; **D.** Withdraw the introducer; **E.** Place the working port in ideal position; **F.** Remove the upper wing (only in this system) and secure the working port with standard retraction system (such as Leyla retractor) or with free hand.

suction with monopolar. However, caution should be taken that the monopolar would not shock the endoscope through the contact with the suction. When specific devices are available, such as Apollo vibration/suction device,[40] it is also a good option. Moreover, some hemostatic agent can be also applied such as Floseal (Baxter) for intraoperative hemostasis.

Localization and navigation

As a fact of limited working space, an accurate localization and navigation will promote the evacuation rate. Across the literature, neuronavigation is the most commonly used method.[36,47] The insertion of the sheath will be navigated to specific target inside the hematoma. Besides the standard navigation system, there are more available options such as using iPhone or iPod to identify the location on scalp of the patient with pre-operative CT.[38,48] Image-guided surgery mainly based on CT to target hypertensive hemorrhage were described by neurosurgeons worldwide instead of neuronavigation.[26,49−53]

The biggest disadvantage of neuronavigation or image-guided localization is intraoperative shift. In compensation for intraoperative shifting, ultrasound is introduced as a real-time navigation for the insertion of the sheath, and it also provides real-time viewing of the hematoma in case of residual.[27,54−56] However, the application of ultrasound may require extra space for ultrasound probe, which may cause additional damage to the patient.

Tips for patients on anti-coagulation medication

The incidence of anticoagulant-related ICH is increasing, as the use of anticoagulants rises. Patients who receive warfarin therapy should use Vitamin K or fresh frozen plasma to reduce the dose of warfarin within 24 h of onset.[57] Reversal of unfractionated heparin can be accomplished with intravenous protamine sulfate.[9]

Indication and timing for endoscopic treatment

There is no commonly agreement on indication and timing for surgical treatment for ICH, and so is with endoscopic treatment. However, study shows that ultra-early surgery (within 4 h from onset) is associated with an increased risk of rebleeding in surgical treatment of ICH.[58] Another study analyzed different surgical treatment of ICH, suggesting when the endoscopic operation was performed within 6−12 h, the mortality rate was lower than conventional craniotomy and drill drainage ($P < 0.05$).[59] In one meta-analysis of randomized controlled trials indicated that patients with supratentorial intracerebral hemorrhage might benefit more from MIS than other treatment options. Patients with GCS score of $\geq$9, hematoma volume between 25 and 40 ml, and within 72 h after onset of symptoms, would benefit more from MIS.[60] The 2014 guidelines from the European Stroke Organization indicated that surgery might be of value in patients with a GCS of 9−12.[61] STICH II trial suggested a potential benefit of early surgical evacuation (within 60 h) in patients with supratentorial hemorrhages between 10 and 100 ml.[3]

Discussion

Theoretically, endoscopic treatment has many techniques underlying. One major advantage of using endoscope is reducing manipulation of viable brain tissue. Instead of conventional retraction with blades, the working channel is provided mostly by a cylinder sheath, which goes directly into the hematoma and serves as a full range retractor with sufficient space for endoscopic evacuation. In order to gain maximal evacuation with the stingy exposure, the port could be gently tilted within the hematoma without excessive retraction. Some systems are designed with transparent scaled sheath and stepwise expansion, extending both visual and special field. The manipulation of the sheath and the flexibility of the visualization from endoscope could compensate for microscopic visual limitations in conventional craniotomy. Moreover, the sheath stands against the surrounding, providing steady hemostasis.

Another advantage of the endoscopic evacuation is the small incision and the delicate craniotomy (sometimes a bur hole), which reduces unnecessary blood loss in large craniotomy.

Catheter drainage, as well as a minimal invasive method for ICH evacuation, has the least blood loss, however, without direct visualization. A major disadvantage of drainage is the difficulty for clots going through the catheter.

A possible solution in this condition is to inject urokinase and flush with sterile saline through the catheter and keep it inside the hematoma cavity for 60 min before reopening the drainage.[62] As a result, the timing and drainage procedure for using catheter drainage would be tricky and restricted compared to other surgical treatment.

Clinically, more and more study illustrated that endoscopic treatment of ICH is superior to conventional craniotomy in modality, motility. The surgery duration

and recover time are shorter than conventional craniotomy, yet with less complication rate. Although the difference in endoscopic group has an overall absolute better outcome, it is still non-statistical significant.

Endoscopic treatment is a potential advanced alternative for ICH, but not yet recommended by guidelines, there are some possible reasons.

Firstly, endoscope, compared to catheters, is still relatively expansive, which may not be available in every hospital, which also requires handle with attention and investment with further annually maintenance.

Secondly, endoscopic techniques are not so commonly acquired compared to microsurgical techniques. Neurosurgeons are more familiar with microscope and microscopic bimanual manipulation in 3-dimensional visions. The 2-dimensional vision and the differences in handling with instruments may discourage some surgeons.

Thirdly, but most importantly, there is no convincing evidence showing a significant advantage of endoscopic treatment over other options. All the data showed a promising trend, but still not powerful enough. Now, more clinical trails are carrying on to figure out the relationships among different methods, especially the comparison between endoscopic and conventional craniotomy. Maybe later with these study, finally comes the commonly agreement on the indication or reliable recommendation.

Studies and experiences published in the past three decades are mostly in favor of evacuating the clot endoscopicly while gaining a promising outcome. The clinical trials through years are changing from testing the feasibility of endoscopic evacuation of ICH to improving outcome by seeking better way of navigation, or decreasing the potential damage.

Conclusion

Many studies have pointed out endoscopic treatment of ICH has better outcomes with less invasive approaches, though no statistical difference compared with conservative medical treatment. However, the difference does encourage further study, because there are still patients who can benefit from this method. Later with better definition in patient selection and proper perisurgical treatment, endoscopic treatment might profit more patient with hypertensive ICH.

Conflicts of interest

Yi-ning Zhao has received national scholarship from Chinese Scholarship Conceal for doctoral degree study in Germany. There is no conflict of interest or relevant affiliation with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript apart from those disclosed.

References

1. Krishnamurthi RV, Feigin VL, Forouzanfar MH, et al. Global and regional burden of first-ever ischaemic and haemorrhagic stroke during 1990−2010: findings from the Global Burden of Disease Study 2010. *Lancet Glob Health*. 2013;1:e259−e281.
2. Hankey GJ. The global and regional burden of stroke. *Lancet Glob Health*. 2013;1:e239−e240.
3. Rennert RC, Signorelli JW, Abraham P, et al. Minimally invasive treatment of intracerebral hemorrhage. *Expert Rev Neurother*. 2015;15:919−933.
4. Adeoye O, Broderick JP. Advances in the management of intracerebral hemorrhage. *Nat Rev Neurol*. 2010;6:593−601.
5. Russell MW, Boulanger L, Joshi AV, et al. The economic burden of intracerebral hemorrhage: evidence from managed care. *Manag Care Interface*. 2006;19:24−28, 34.
6. Ikram MA, Wieberdink RG, Koudstaal PJ. International epidemiology of intracerebral hemorrhage. *Curr Atheroscler Rep*. 2012;14:300−306.
7. Ariesen MJ, Claus SP, Rinkel GJ, et al. Risk factors for intracerebral hemorrhage in the general population: a systematic review. *Stroke*. 2003;34:2060−2065.
8. O'Donnell MJ, Xavier D, Liu L, et al. Risk factors for ischaemic and intracerebral haemorrhagic stroke in 22 countries (the INTERSTROKE study): a case-control study. *Lancet*. 2010;376:112−123.
9. Flaherty ML. Anticoagulant-associated intracerebral hemorrhage. *Semin Neurol*. 2010;30:565−572.
10. Elkind MS, Sacco RL. Direct thrombin inhibition: a novel approach to stroke prevention in patients with atrial fibrillation. *Stroke*. 2004;35:1519−1522.
11. Gonzalez-Duarte A, Cantu C, Ruiz-Sandoval JL, Barinagarrementeria F. Recurrent primary cerebral hemorrhage: frequency, mechanisms, and prognosis. *Stroke*. 1998;29:1802−1805.
12. Ruiz-Sandoval JL, Cantu C, Barinagarrementeria F. Intracerebral hemorrhage in young people: analysis of risk factors, location, causes, and prognosis. *Stroke*. 1999;30:537−541.
13. Hemphill 3rd JC, Greenberg SM, Anderson CS, et al. Guidelines for the management of spontaneous intracerebral hemorrhage: a guideline for healthcare Professionals from the American Heart Association/American Stroke Association. *Stroke*. 2015;46:2032−2060.
14. Mendelow AD, Investigators and the Steering Committee. The International Surgical Trial in Intracerebral Haemorrhage (ISTICH). *Acta Neurochir Suppl*. 2003;86:441−443.
15. Zheng J, Li H, Guo R, et al. Minimally invasive surgery treatment for the patients with spontaneous supratentorial intracerebral hemorrhage (MISTICH): protocol of a multi-center randomized controlled trial. *BMC Neurol*. 2014;14:206.
16. Mendelow AD. Surgical trial in intracerebral haemorrhage (S.T.I.C.H). *Acta Neurochir Suppl*. 2000;76:521−522.
17. Gregson BA, Murray GD, Mitchell PM, et al. Update on the Surgical Trial in Lobar Intracerebral Haemorrhage (STICH II): statistical analysis plan. *Trials*. 2012;13:222.

18. Li N, Liu YF, Ma L, et al. Association of molecular markers with perihematomal edema and clinical outcome in intracerebral hemorrhage. *Stroke*. 2013;44:658−663.
19. Li N, Worthmann H, Heeren M, et al. Temporal pattern of cytotoxic edema in the perihematomal region after intracerebral hemorrhage: a serial magnetic resonance imaging study. *Stroke*. 2013;44:1144−1146.
20. Gaberel T, Magheru C, Emery E. Management of non-traumatic intraventricular hemorrhage. *Neurosurg Rev*. 2012;35:485−494; discussion 494−485.
21. Mould WA, Carhuapoma JR, Muschelli J, et al. Minimally invasive surgery plus recombinant tissue-type plasminogen activator for intracerebral hemorrhage evacuation decreases perihematomal edema. *Stroke*. 2013;44:627−634.
22. Auer LM, Deinsberger W, Niederkorn K, et al. Endoscopic surgery versus medical treatment for spontaneous intracerebral hematoma: a randomized study. *J Neurosurg*. 1989;70:530−535.
23. Feng Y, He J, Liu B, et al. Endoscope-assisted keyhole technique for hypertensive cerebral hemorrhage in elderly patients: a randomized controlled study in 184 patients. *Turk Neurosurg*. 2016;26:84−89.
24. Nagasaka T, Tsugeno M, Ikeda H, et al. Early recovery and better evacuation rate in neuroendoscopic surgery for spontaneous intracerebral hemorrhage using a multifunctional cannula: preliminary study in comparison with craniotomy. *J Stroke Cerebrovasc Dis*. 2011;20:208−213.
25. Angileri FF, Esposito F, Priola SM, et al. Fully endoscopic freehand evacuation of spontaneous supratentorial intraparenchymal hemorrhage. *World Neurosurg*. 2016;94:268−272.
26. Dye JA, Dusick JR, Lee DJ, et al. Frontal bur hole through an eyebrow incision for image-guided endoscopic evacuation of spontaneous intracerebral hemorrhage. *J Neurosurg*. 2012;117:767−773.
27. Kuo LT, Chen CM, Li CH, et al. Early endoscope-assisted hematoma evacuation in patients with supratentorial intracerebral hemorrhage: case selection, surgical technique, and long-term results. *Neurosurg Focus*. 2011;30:E9.
28. Auer LM. Endoscopic evacuation of intracerebral haemorrhage. High-tec-surgical treatment−a new approach to the problem? *Acta Neurochir (Wien)*. 1985;74:124−128.
29. Koziolek MJ, Lüders S. Blood pressure treatment in the acute stage of stroke [in German]. *Dtsch Med Wochenschr*. 2015;140:1587−1592.
30. Morgan T, Zuccarello M, Narayan R, et al. Preliminary findings of the minimally-invasive surgery plus rtPA for intracerebral hemorrhage evacuation (MISTIE) clinical trial. *Acta Neurochir Suppl*. 2008;105:147−151.
31. Chen CC, Lin HL, Cho DY. Endoscopic surgery for thalamic hemorrhage: a technical note. *Surg Neurol*. 2007;68:438−442; discussion 442.
32. Chen CC, Cho DY, Chang CS, et al. A stainless steel sheath for endoscopic surgery and its application in surgical evacuation of putaminal haemorrhage. *J Clin Neurosci*. 2005;12:937−940.
33. McLaughlin N, Kelly DF, Prevedello DM, Carrau RL, Kassam AB. Hemostasis management during completely endoscopic removal of a highly vascular intraparenchymal brain tumor: technique assessment. *J Neurol Surg A Cent Eur Neurosurg*. 2014;75:42−47.
34. Kassam AB, Engh JA, Mintz AH, et al. Completely endoscopic resection of intraparenchymal brain tumors. *J Neurosurg*. 2009;110:116−123.
35. Wang WH, Hung YC, Hsu SP, et al. Endoscopic hematoma evacuation in patients with spontaneous supratentorial intracerebral hemorrhage. *J Chin Med Assoc*. 2015;78:101−107.
36. Waran V, Vairavan N, Sia SF, et al. A new expandable cannula system for endoscopic evacuation of intraparenchymal hemorrhages. *J Neurosurg*. 2009;111:1127−1130.
37. Sun GC, Chen XL, Hou YZ, et al. Image-guided endoscopic surgery for spontaneous supratentorial intracerebral hematoma. *J Neurosurg*. 2016:1−6.
38. Hou Y, Ma L, Zhu R, et al. iPhone-assisted augmented reality localization of basal ganglia hypertensive hematoma. *World Neurosurg*. 2016;94:480−492.
39. Angileri FF, Esposito F, Priola SM, et al. Fully endoscopic freehand evacuation of spontaneous supratentorial intraparenchymal hemorrhage: technical note. *World Neurosurg*. 2016;94:268−272.
40. Tan LA, Lopes DK, Munoz LF, et al. Minimally invasive evacuation of intraventricular hemorrhage with the Apollo vibration/suction device. *J Clin Neurosci*. 2016;27:53−58.
41. Orakcioglu B, Uozumi Y, Unterberg A. Endoscopic intrahematomal evacuation of intracerebral hematomas − a suitable technique for patients with coagulopathies. *Acta Neurochir Suppl*. 2011;112:3−8.
42. Dye JA, Dusick JR, Lee DJ, et al. Frontal bur hole through an eyebrow incision for image-guided endoscopic evacuation of spontaneous intracerebral hemorrhage. *J Neurosurg*. 2012;117:767−773.
43. Zhu H, Wang Z, Shi W. Keyhole endoscopic hematoma evacuation in patients. *Turk Neurosurg*. 2012;22:294−299.
44. Feng Y, He J, Liu B, et al. Endoscope-assisted keyhole technique for hypertensive cerebral hemorrhage in elderly patients: a randomized controlled study in 184 patients. *Turk Neurosurg*. 2016;26:84−89.
45. Liu L, Liu X, Zhang F, et al. Dual-channel minimally invasive endoscopic port for evacuation of deep-seated spontaneous intracerebral hemorrhage with obstructive hydrocephalus. *World Neurosurg*. 2016;91:452−459.
46. Nagasaka T, Inao S, Ikeda H, et al. Inflation-deflation method for endoscopic evacuation of intracerebral haematoma. *Acta Neurochir (Wien)*. 2008;150:685−690; discussion 690.
47. Carvi y Nievas MN, Haas E, Höllerhage HG, et al. Combined minimal invasive techniques in deep supratentorial intracerebral haematomas. *Minim Invasive Neurosurg*. 2004;47:294−298.
48. Chen X, Xu BN, Yu XG. iPod touch-assisted instrumentation of the spine: is it accurate and reliable? *Neurosurgery*. 2014;75:E734−E736.
49. Lin HL, Lo YC, Chen CC, et al. Three-dimensional reconstructed CT scanning for targeting hypertensive putaminal hemorrhage. *J Clin Neurosci*. 2008;15:693−696.
50. Miller CM, Vespa P, Saver JL, et al. Image-guided endoscopic evacuation of spontaneous intracerebral hemorrhage. *Surg Neurol*. 2008;69:441−446; discussion 446.
51. Fiorella D, Arthur AS, Mocco JD. 305 The INVEST trial: a randomized, controlled trial to Investigate the Safety and efficacy of image-guided minimally invasive endoscopic surgery with Apollo vs best medical management for supratentorial intracerebral hemorrhage. *Neurosurgery*. 2016;63:187.
52. Fujisawa M, Yamashita S, Katagi R. Usefulness of intraoperative computed tomography for the evacuation of lobar hemorrhage. *Acta Neurochir Suppl*. 2013;118:175−179.

53. Voges J, Schröder R, Treuer H, et al. CT-guided and computer assisted stereotactic biopsy. Technique, results, indications. *Acta Neurochir (Wien)*. 1993;125:142−149.
54. Sadahiro H, Nomura S, Goto H, et al. Real-time ultrasound-guided endoscopic surgery for putaminal hemorrhage. *J Neurosurg*. 2015;123:1151−1155.
55. Auer LM. Intraoperative ultrasound as guide for neurosurgical endoscopic procedures. *Acta Radiol Suppl*. 1986;369:164−166.
56. Chiu WT, Chen SY, Lin JW, et al. Color-Doppler Ultrasound-assisted endoscopic neurosurgery for intracerebral hemorrhage. *Zhonghua Yi Xue Za Zhi (Taipei)*. 1996;57:198−203.
57. Yasaka M, Minematsu K, Naritomi H, et al. Predisposing factors for enlargement of intracerebral hemorrhage in patients treated with warfarin. *Thromb Haemost*. 2003;89:278−283.
58. Morgenstern LB, Demchuk AM, Kim DH, et al. Rebleeding leads to poor outcome in ultra-early craniotomy for intracerebral hemorrhage. *Neurology*. 2001;56:1294−1299.
59. Chi FL, Lang TC, Sun SJ, et al. Relationship between different surgical methods, hemorrhage position, hemorrhage volume, surgical timing, and treatment outcome of hypertensive intracerebral hemorrhage. *World J Emerg Med*. 2014;5:203−208.
60. Zhou X, Chen J, Li Q, et al. Minimally invasive surgery for spontaneous supratentorial intracerebral hemorrhage: a meta-analysis of randomized controlled trials. *Stroke*. 2012;43:2923−2930.
61. Steiner T, Al-Shahi Salman R, Beer R, et al. European Stroke Organisation (ESO) guidelines for the management of spontaneous intracerebral hemorrhage. *Int J Stroke*. 2014;9:840−855.
62. Tan Q, Chen Q, Niu Y, et al. Urokinase, a promising candidate for fibrinolytic therapy for intracerebral hemorrhage. *J Neurosurg*. 2016:1−10.

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