Surveillance neuroimaging and neurologic examinations affect care for intracerebral hemorrhage

Matthew B. Maas, MD
Neil F. Rosenberg, MD
Adam R. Kosteva, MA
Rebecca M. Bauer, MD,
MPH

James C. Guth, MD
Eric M. Liotta, MD
Shyam Prabhakaran, MD,
MS

Andrew M. Naidech,
MD, MSPH

Correspondence to
Dr. Maas:
mbmaas@northwestern.edu

ABSTRACT

Objective: We tested the hypothesis that surveillance neuroimaging and neurologic examinations identified changes requiring emergent surgical interventions in patients with intracerebral hemorrhage (ICH).

Methods: Patients with primary ICH were enrolled into a prospective registry between December 2006 and July 2012. Patients were managed in a neuroscience intensive care unit with a protocol that included serial neuroimaging at 6, 24, and 48 hours, and hourly neurologic examinations using the Glasgow Coma Scale and NIH Stroke Scale. We evaluated all cases of craniotomy and ventriculostomy to determine whether the procedure was part of the initial management plan or occurred subsequently. For those that occurred subsequently, we determined whether worsening on neurologic examination or worsened neuroimaging findings initiated the process leading to intervention.

Results: There were 88 surgical interventions in 84 (35%) of the 239 patients studied, including ventriculostomy in 52 (59%), craniotomy in 21 (24%), and both in 11 (13%). Of the 88 interventions, 24 (27%) occurred subsequently and distinctly from initial management, a median of 15.9 hours (8.9–27.0 hours) after symptom onset. Thirteen (54%) were instigated by findings on neurologic examination and 11 (46%) by neuroimaging. Demographics, severity of hemorrhage, and hemorrhage location were not associated with delayed intervention.

Conclusions: More than 25% of surgical interventions performed after ICH were prompted by delayed imaging or clinical findings. Serial neurologic examinations and neuroimaging are important and effective surveillance techniques for monitoring patients with ICH. *Neurology*® 2013;81:107–112

GLOSSARY

GCS = Glasgow Coma Scale; **ICH** = intracerebral hemorrhage; **IRB** = institutional review board; **IVH** = intraventricular hemorrhage; **mRS** = modified Rankin Scale; **NIHSS** = NIH Stroke Scale.

The 1-year mortality from intracerebral hemorrhage (ICH) exceeds 50%, the majority of survivors are left disabled, and outcomes do not appear to be improving despite considerable research advances.¹ Rapid identification and management of in-hospital complications is a potential means of improving outcomes. Hematoma growth and delayed intraventricular extension occur in some patients with ICH and are associated with worse outcome, for example, but whether any system of monitoring for those complications affects patient care is unknown.^{2,3}

Neither the US nor European guidelines on management of ICH comment on neuroimaging for purposes other than diagnosis and evaluation of hemorrhage etiology.^{4,5} Likewise, the guidelines cite evidence to recommend initial management in units with neuroscience expertise, but the effective components of such specialized care remain to be elucidated. We sought to test the hypothesis that a structured surveillance protocol that includes serial neuroimaging and neurologic examinations identifies clinical changes requiring emergent surgical interventions. As a secondary analysis, we sought to identify any predictors of subsequent surgical intervention among patients who do not undergo immediate surgery after initial evaluation.

METHODS Patients presenting to Northwestern Memorial Hospital with ICH between December 2006 and July 2012 were prospectively enrolled in an observational cohort study. All cases were diagnosed by a board-certified vascular neurologist or

Editorial, page 102

From the Departments of Neurology (M.B.M., N.F.R., A.R.K., J.C.G., E.M.L., S.P., A.M.N.) and Anesthesiology (M.B.M., R.M.B., A.M.N.), Northwestern University, Chicago, IL.

Go to Neurology.org for full disclosures. Funding information and disclosures deemed relevant by the authors, if any, are provided at the end of the article.

neurointensivist utilizing CT or MRI. Patients with ICH attributed to trauma, hemorrhagic conversion of ischemic stroke, structural lesions, or vascular malformations were excluded. All patients were admitted to a neurointensive care unit with a standard order set in the electronic order entry system. Given the association between reduced platelet activity and early hematoma growth after ICH, we routinely measured platelet activity on admission, and defined aspirin resistance units <550 as indicative of platelet dysfunction, as previously described.⁶

Neuroimaging surveillance. Per protocol, patients underwent serial noncontrast CT imaging to monitor for expansion of the hematoma, hydrocephalus, intraventricular extension of hemorrhage, and cerebral edema at intervals of 6, 24, and 48 hours after the initial brain imaging, although earlier imaging was obtained stat due to a change in clinical status or deferred in the case of medical instability or withdrawal of life support. Beyond 48 hours, serial neuroimaging was preordered to be done daily in patients deemed to be at high risk for deterioration from hydrocephalus or cerebral edema. The routine first 3 surveillance neuroimaging studies were preordered at the time of admission, and emergent neuroimaging to further evaluate clinical deterioration was ordered stat at the time of requisition. At the discretion of the clinical team, CT angiography was performed, usually as a distinct study within the first 6 hours. MRI was obtained whenever feasible in patients unlikely to die within 48 hours from ICH symptom onset on Siemens 1.5-T MR scanners (Siemens AG, Munich, Germany) with a protocol including B1000, diffusion-weighted images, apparent diffusion coefficient maps, fluid-attenuated inversion recovery, T2/turbo spin echo, and T1 and T2* gradient echo, as previously described.⁷

Neurologic examination surveillance. The neurointensive care unit was staffed with registered nurses with additional training and certification in neuroscience nursing and structured, specific training in the administration of standardized neurologic examination instruments, including the Glasgow Coma Scale (GCS) and NIH Stroke Scale (NIHSS). Per protocol, neurologic examinations were performed hourly by the patients' primary nurse, and the primary responding physician was notified of any change in neurologic function detected. Specifically, the official hospital protocol for ICH management requires that the complete NIHSS be performed independently by a neuroscience nurse on admission and 12 hours after admission, and that the complete GCS be performed by a neuroscience nurse on admission and hourly thereafter throughout the entire stay in the intensive care unit. Beginning in December 2009, the NIHSS and GCS were populated into the electronic medical record. To emphasize the requirement for complete and independent assessments, copying forward of assessments entered by nurses from a prior shift is not allowed in the electronic medical record. Additionally, all patients were examined at regular intervals, at least twice daily, by critical care physicians including a board-certified intensivist with experience managing neurologic critical care and physicians from the neurology or neurosurgery teams.

Demographic information, medical history, medication history, standardized clinical instruments (GCS, NIHSS, pre-ICH modified Rankin Scale [mRS]), pretreatment blood pressure, laboratory data, imaging data, medical management variables, surgical interventions, and medical complications were prospectively recorded. A certified examiner independent of the primary clinical team recorded the NIHSS and mRS at 14 days or discharge, whichever came first. The mRS was also recorded prospectively at 28 days and 3 months with a validated questionnaire.^{8,9} Hematoma volumes were measured on industry standard DICOM images from both referring hospitals and ours using Analyze software (Mayo Clinic, Rochester, MN) with a semiautomated process, a technique with high

reliability that has been used as an endpoint in other ICH studies, as we have previously described.⁶

Determining the indicator for surgical intervention. We prospectively recorded every case where a craniotomy for hematoma evacuation or craniectomy for hematoma evacuation and decompression ("craniotomy"), or ventriculostomy by external ventricular drain placement ("ventriculostomy") for hydrocephalus or intraventricular hemorrhage (IVH), had occurred. We reviewed each of these in the electronic medical record to determine the objective and proximate clinical circumstances leading to the intervention. In general, craniotomies were performed on patients with large (>30 mL) superficial lobar hemorrhages exerting life-threatening mass effect to reduce the chance of death, or on cerebellar hemorrhages at risk for or causing brainstem compression or ventricular obstruction. Ventriculostomies were performed in patients with hydrocephalus or IVH and diminished level of arousal. These indications are consistent with guideline recommendations.^{4,5} The surgical interventions were performed as soon as feasible once the patient met the above criteria for intervention. Of note, there were cases who met criteria for a surgical intervention but did not undergo a procedure when a discussion with the patient's surrogate identified circumstances, usually severe comorbidities limiting the patient's life expectancy or quality of life, that led to limitation in the scope of their acute care.

Physician and nursing documentation was reviewed to identify whether clinical reassessment in these cases was instigated by a change in neurologic examination or findings on a surveillance neuroimaging study. The adjudication considered nursing GCS documentation, narrative nursing note, whether the proximate preceding neuroimaging study was a preordered surveillance examination per protocol or stat examination in response to clinical change, whether the preceding neuroimaging study demonstrated new or worsened findings, and the narrative chart entries by the critical care, neurology, and neurosurgery physician staff.

Cases were judged to be initial management when interventions were performed as soon as feasible after the initial clinical assessment and diagnostic neuroimaging, and as expressed in the initial neurosurgical assessment. Interventions occurring as subsequent management decisions were judged as scan initiated if 1) they occurred directly after a preordered surveillance neuroimaging study that showed worsened findings, 2) physician documentation cited worsened imaging findings as the indicator for the intervention, and 3) examination worsening was either not mentioned or documentation is clear that repeat neurologic examination occurred in response to new neuroimaging findings. Subsequent interventions were judged as examination initiated if 1) examination worsening is cited in documentation as the indicator for the intervention, 2) no worsening is noted on preceding neuroimaging, or 3) a stat neuroimaging study had been ordered in response to an examination worsening. Finally, we identified cases where the intervention occurred in a delayed fashion due to logistical circumstances or change in surrogates' decisions, and categorized those interventions as initial management if that was the initial recommendation of the medical team.

Fisher exact test was used to compare the number of scan-initiated vs examination-initiated interventions to see whether the proportion was significantly different. To assess for predictors of subsequent surgical intervention that was not part of the initial management plan, we planned to identify variables associated with subsequent intervention on univariate analysis, and to enter those variables with $p < 0.2$ into a logistic regression model to identify for independent predictors.

Standard protocol approvals, registrations, and patient consents. The study was approved by the institutional review

board (IRB). Written informed consent was obtained from the patient or a legally authorized representative. The IRB approved a waiver of consent for patients who died during initial hospitalization, or who were incapacitated and for whom a legal representative could not be located.

RESULTS There were 239 patients in the study cohort, 155 (65%) of whom had no surgical intervention. The demographic and clinical characteristics of the cohort are summarized in table 1. Eighty-four patients underwent 88 discrete surgical interventions, including ventriculostomy in 52 (59%), craniotomy in 21 (24%), and craniotomy with concurrent ventriculostomy in 11 (13%). Sixty-four (73%) of the surgical interventions were part of the initial management plan, and 24 (27%) were subsequent management decisions, occurring at a median of 15.9 hours (interquartile range 8.9–27.0) from symptom onset. There were 2 cases of intervention delay due to surrogate decision makers revising their consent decision and one case of logistical delay. Those cases were all categorized as initial management interventions, consistent with the intentions of the medical team. A total of 13 (54%) surgical interventions were examination initiated and 11 (46%) were scan initiated ($p = 0.8$). Sample data illustrating cases identified as examination initiated and scan initiated are shown in table 2. The observed interventions are summarized in the figure.

Table 1 Patient demographic and clinical variables

Characteristics	Values
Male, n (%)	116 (49.0)
Age, y, mean (SD)	65 (14)
Race (white), n (%)	100 (41.8)
Glasgow Coma Scale, median (IQR)	13 (8–15)
ICH score, median (IQR)	1 (0–3)
Initial hematoma volume, mL, median (IQR)	12 (5–30)
Prior intracerebral hemorrhage, n (%)	9 (3.8)
Prior ischemic stroke, n (%)	32 (13.4)
Coronary artery disease, n (%)	44 (18.4)
Hypertension, n (%)	178 (74.5)
Diabetes mellitus, n (%)	48 (20.1)
International normalized ratio, median (IQR)	1.10 (1.00–1.20)
Aspirin resistance units <550, n (%)	100 (41.8)
Initial systolic blood pressure, mm Hg, mean (SD)	183 (41)
Initial diastolic blood pressure, mm Hg, mean (SD)	98 (28)
Initial blood glucose, mg/dL, mean (SD)	151 (71)

Abbreviations: ICH = intracerebral hemorrhage; IQR = interquartile range.

Among variables available for clinical decision-making in the initial evaluation period, ICH score was associated with the need for a subsequent surgical intervention among patients who did not undergo immediate surgical intervention ($p = 0.045$), with trends also present for lower age ($p = 0.09$), higher initial systolic and diastolic blood pressure ($p = 0.06$ and 0.16), greater platelet dysfunction ($p = 0.11$), and IVH present on initial imaging ($p = 0.09$). None of those variables remained significant in the multivariate model. Analysis of surveillance neuroimaging findings showed that delayed IVH and hematoma growth (whether measured as absolute growth or percent growth) were associated with delayed intervention (all $p < 0.01$). The results of these secondary analyses are shown in table 3.

DISCUSSION In this large prospective cohort of subjects with ICH, we found that more than 10% of patients underwent surgical interventions that became necessary after the period of initial evaluation and stabilization. Delayed intraventricular extension and hematoma growth on follow-up neuroimaging were strongly associated with subsequent intervention, and both surveillance neuroimaging and serial neurologic examinations by trained staff were effective at identifying in-hospital worsening amenable to surgical intervention. Considering that no commonly acquired demographic, radiographic, or clinical variable was identified as a predictor of the need for subsequent intervention, these surveillance techniques are important and justify specialized critical care monitoring.

The purpose of neurologic monitoring is to detect clinically relevant changes in the function and structure of the nervous system. While the role of surveillance neuroimaging and examinations has been studied in various groups of head trauma patients, there has been no similar study in patients with ICH.¹⁰ Although a variety of invasive and noninvasive neuromonitoring instruments are under investigation, basic structural neuroimaging and standardized neurologic examinations are familiar and widely applied monitoring techniques. ICH is a dynamic process, and critical changes are known to evolve beyond the time of initial assessment. Several detectable complications may be amenable to intervention. Hematoma growth has been associated with worse outcomes in several studies.³ We recently reported that delayed intraventricular extension of hemorrhage occurs in 21% of patients with no IVH on initial imaging, and was independently associated with death and worse 3-month outcomes.² Furthermore, the majority of clinicians use some combination of serial neurologic examinations and neuroimaging to guide therapeutic decisions on osmotherapy for cerebral edema.¹¹

We have previously reported that reduced platelet activity is associated with more IVH, hematoma

Table 2 Sample cases of examination- versus scan-initiated intervention determination

Timeline		Neuroimaging surveillance	Neurologic examination surveillance
Case 1: Examination-initiated ventriculostomy in a 54-year-old patient with right thalamic hemorrhage ^a			
Day 0			
15:00	Symptom onset		
Day 1			
09:15	ED triage arrival		
09:38	Initial diagnostic neuroimaging	Right thalamic hemorrhage, mass effect on third ventricle, and mild hydrocephalus	
13:06	Neuroimaging	No significant change	
15:45	Arrival in ICU		
16:00	Neurologic examination	GCS = 15	
20:00	Neurologic examination	GCS = 15	
21:29	Neuroimaging	No significant change	
23:00	Neurologic examination	GCS = 8	
23:00	Nursing: “notified neurology and neurosurgery”		
Day 2			
00:00	Ventriculostomy performed		
04:00	Neurologic examination	GCS = 9	
08:00	Neurologic examination	GCS = 14	
Case 2: Neuroimaging-initiated craniotomy in a 40-year-old patient with 117-mL right frontotemporal hemorrhage ^b			
Day 0			
13:30	Symptom onset		
14:27	Initial diagnostic neuroimaging	Large right-sided hemorrhage	
18:00	Arrival in ICU from outside hospital		
18:00	Neurologic examination	GCS = 14	
18:58	Neuroimaging	New intraventricular extension, mass effect, and right to left midline shift	
20:00	Neurologic examination	GCS = 14	
23:03	Neuroimaging	Hematoma expansion, increased edema, and mild to moderate mass effect	
Day 1			
03:00	Neurologic examination	GCS = 15	
05:58	Neuroimaging	Further increased edema and mass effect, right to left subfalcine herniation	
08:00	Neurologic examination	GCS = 14	
11:00	Craniotomy performed		

Abbreviations: ED = emergency department; EVD = external ventricular drain; GCS = Glasgow Coma Scale; HCP = hydrocephalus; hCT = head CT; ICH = intracerebral hemorrhage; ICU = intensive care unit; IPH = intraparenchymal hemorrhage; NSGY = neurosurgery; Pt = patient.

^aNeurology attending note: "During the evening yesterday [patient] became more lethargic and got EVD for ventriculomegaly, with improvement in [their] overall level of alertness." Neurosurgery note: "Last night was more sleepy, no longer responding to voice or following commands. hCT showed stable HCP and right thalamic IPH. However, given change in neuro exam, urgent EVD placed for decompression."

^bNeurology attending note: "Serial head CTs show large ICH w evolving mass effect and R to L shift...Pt at high risk for further swelling/edema/possible herniation as ICH evolves; discussed case w family, NSGY consult team, and Dr. X; I feel that early NSGY intervention would be beneficial to prevent potential herniation syndrome." Neurosurgery attending note: "Dr. X and Dr. X consulted me this morning with concerns that [patient] should be decompressed. [Patient] had a sizable right-sided hematoma that created significant mass effect. The patient was hemiplegic and, at the time I examined [patient], [patient] was communicating reasonably with [their] family. The concern was that with [their] shift [they] would likely deteriorate."

growth, and craniotomy, but we did not analyze the time course.^{6,12,13} In the way that warfarin use is associated with delayed hematoma growth, reduced platelet activity may also predispose to subacute worsening, thus

the trend we observed for more delayed interventions in patients with platelet dysfunction.¹⁴ Whether correcting reduced platelet activity would reduce the need for later interventions is unknown.

Figure Observed interventions and initiating events in the ICH cohort

ICH = primary intracerebral hemorrhage.

Craniotomy or ventriculostomy is not indicated for all patients with hematoma growth, hydrocephalus, or IVH, so previously published studies describing those imaging findings are inadequate alone to determine whether monitoring interventions actually affect care. This study does not address whether the surgical interventions initiated on the basis of examination or imaging findings affect patient morbidity or mortality and therefore must be interpreted in the context of the surgical literature. There is considerable consensus in favor of surgical interventions in patients with cerebellar hemorrhages, and hydrocephalus or IVH with diminished level of arousal.^{4,5} The role of craniotomy for supratentorial ICH is still under investigation. The STICH trial, which enrolled subjects for whom the benefit of surgery was uncertain, demonstrated no clear favor of surgery in unselected ICH, although secondary analysis suggested benefit for patients with superficial lobar hemorrhages (the subject of STICH-2).¹⁵ In that study population of medium severity patients, 26% of those randomized to medical management later required surgery, predominantly for hemorrhage expansion or neurologic deterioration, the changes that surveillance neuroimaging and neurologic examinations are intended to detect.¹⁵ Despite less standardized

Table 3 Predictors of delayed intervention

Variable	No delayed intervention	Delayed intervention	Univariate p	Multivariate p
% Male	50	55	0.82	
Age, y, mean	66	60	0.09	(Included in ICH score)
Race, % white	39	55	0.25	
Glasgow Coma Scale, median	14	13	0.17	
ICH score, median	1	2	0.045	0.30
Initial hematoma volume, mL, median	10.0	10.8	0.53	
Prior intracerebral hemorrhage, %	5	0	0.60	
Prior ischemic stroke, %	15	5	0.32	
Coronary artery disease, %	20	18	0.99	
Hypertension, %	76	86	0.42	
Diabetes mellitus, %	23	27	0.79	
International normalized ratio, median	1.10	1.10	0.66	
Aspirin resistance units <550, %	36	55	0.11	0.12
Initial systolic BP, mm Hg, mean	180	199	0.06	0.25
Initial diastolic BP, mm Hg, mean	96	105	0.16	0.83
Initial blood glucose, mg/dL, mean	148	154	0.70	
IVH on initial presentation, %	31	50	0.09	(Included in ICH score)
Surveillance imaging findings associated with delayed intervention				
Delayed IVH, %	8	32	0.005	
Absolute hematoma growth, mL, median	0	3.4	<0.001	
Percent hematoma growth, mL, median	0%	23%	<0.001	

Abbreviations: BP = blood pressure; ICH = intracerebral hemorrhage; IVH = intraventricular hemorrhage.

indicators for intervention, need for neurosurgical intervention has been an accepted endpoint in studies of clinical and imaging evaluation strategies in head trauma.¹⁶

Patients in our cohort were systematically evaluated for surgical interventions with careful attention to published guidelines and major trial results. The results we observed should generalize to other institutions where evidence-based care directs surgical practice, although there is likely to be heterogeneity of surgical practice between institutions. We did not consider osmotherapy interventions in our analysis, given that medical management practices are not standardized.¹¹ Further study to clarify the impact of surveillance on other interventions, such as osmotherapy, would be informative. Despite the rigorous methods used, this work is still limited by being a single-center study. Furthermore, it is uncertain whether deterioration identified first by neuroimaging would have eventually been detected by examinations, and what the clinical impact of that delay would have been. Finally, although we did not assess the impact of cumulative radiation exposure, this may be attenuated by increased utilization of rapid acquisition MRI techniques.

The importance of surveillance neuroimaging and examinations may be intuitive to experienced practitioners, yet resource utilization must be rationalized by evidence as health care providers become increasingly accountable for costs associated with hospital care. These data demonstrate that surveillance neuroimaging and neurologic examinations lead to unplanned subsequent intervention. Further research is needed to determine the ideal assessment intervals and duration of surveillance.

AUTHOR CONTRIBUTIONS

Matthew B. Maas: study concept and design, data acquisition, data and imaging analysis and interpretation, drafting manuscript. Neil F. Rosenberg: data acquisition, critical revision of the manuscript for important intellectual content. Adam R. Kosteva: data acquisition, critical revision of the manuscript for important intellectual content. Rebecca M. Bauer: critical revision of the manuscript for important intellectual content. James C. Guth: critical revision of the manuscript for important intellectual content. Eric M. Liotta: critical revision of the manuscript for important intellectual content. Shyam Prabhakaran: critical revision of the manuscript for important intellectual content. Andrew M. Naidech: data acquisition, critical revision of the manuscript for important intellectual content, study supervision.

STUDY FUNDING

No targeted funding reported.

DISCLOSURE

M.B. Maas receives funding from the NIH Loan Repayment Program. N.F. Rosenberg, A.R. Kosteva, R.M. Bauer, J.C. Guth, E.M. Liotta, S. Prabhakaran, and A.M. Naidech report no disclosures. Go to Neurology.org for full disclosures.

Received November 19, 2012. Accepted in final form March 7, 2013.

REFERENCES

1. Flaherty ML, Haverbusch M, Sekar P, et al. Long-term mortality after intracerebral hemorrhage. *Neurology* 2006; 66:1182–1186.
2. Maas MB, Nemeth AJ, Rosenberg NF, Kosteva AR, Prabhakaran S, Naidech AM. Delayed intraventricular hemorrhage is common and worsens outcomes in intracerebral hemorrhage. *Neurology* 2013;80:1295–1299.
3. Dowlatshahi D, Demchuk AM, Flaherty ML, et al. Defining hematoma expansion in intracerebral hemorrhage: relationship with patient outcomes. *Neurology* 2011;76: 1238–1244.
4. Morgenstern LB, Hemphill JC, Anderson C, et al. Guidelines for the management of spontaneous intracerebral hemorrhage: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke* 2010;41:2108–2129.
5. European Stroke Initiative Writing Committee and the Writing Committee for the EUSI Executive Committee. Recommendations for the management of intracranial haemorrhage: part I: spontaneous intracerebral haemorrhage. *Cerebrovasc Dis* 2006;22:294–316.
6. Naidech AM, Jovanovic B, Liebling S, et al. Reduced platelet activity is associated with early clot growth and worse 3-month outcome after intracerebral hemorrhage. *Stroke* 2009;40:2398–2401.
7. Garg RK, Liebling SM, Maas MB, Nemeth AJ, Russell EJ, Naidech AM. Blood pressure reduction, decreased diffusion on MRI, and outcomes after intracerebral hemorrhage. *Stroke* 2012;43:67–71.
8. Banks JL, Marotta CA. Outcomes validity and reliability of the modified Rankin scale: implications for stroke clinical trials: a literature review and synthesis. *Stroke* 2007; 38:1091–1096.
9. Wilson JT, Hareendran A, Grant M, et al. Improving the assessment of outcomes in stroke: use of a structured interview to assign grades on the modified Rankin scale. *Stroke* 2002;33:2243–2246.
10. Bee TK, Magnotti LJ, Croce MA, et al. Necessity of repeat head CT and ICU monitoring in patients with minimal brain injury. *J Trauma* 2009;66:1015–1018.
11. Hays A, Lazaridis C, Neyens R, Nicholas J, Gay S, Chalela J. Osmotherapy: use among neurointensivists. *Neurocrit Care* 2011;14:222–228.
12. Naidech AM, Bendok BR, Garg RK, et al. Reduced platelet activity is associated with more intraventricular hemorrhage. *Neurosurgery* 2009;65:684–688.
13. Naidech AM, Rosenberg NF, Bernstein RA, Batjer HH. Aspirin use or reduced platelet activity predicts craniotomy after intracerebral hemorrhage. *Neurocrit Care* 2011;15: 442–446.
14. Flibotte JJ, Hagan N, O'Donnell J, Greenberg SM, Rosand J. Warfarin, hematoma expansion, and outcome of intracerebral hemorrhage. *Neurology* 2004;63:1059–1064.
15. Mendelow AD, Gregson BA, Fernandes HM, et al. Early surgery versus initial conservative treatment in patients with spontaneous supratentorial intracerebral haematomas in the international Surgical Trial in Intracerebral Haemorrhage (STICH): a randomised trial. *Lancet* 2005;365:387–397.
16. Bouida W, Marghli S, Souissi S, et al. Prediction value of the Canadian CT head rule and the New Orleans criteria for positive head CT scan and acute neurosurgical procedures in minor head trauma: a multicenter external validation study. *Ann Emerg Med* 2013;61:521–527.