

THE BIGGER PICTURE OF LARGE HEMISPHERIC INFARCTION

Disease and Management

TODAY'S PANELISTS

Panel Chair



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Expert Panelists

OBJECTIVES



Review complexities associated with the diagnosis, treatment, and management of LHI



Understand key considerations and decision points throughout the journey of a patient with LHI



Discuss forward-looking strategies to optimize patient outcomes

LHI, large hemispheric infarction.

Audience Question: What is your primary specialty?



Please go to **Slido.com** to participate in the audience response questions

- Event code: **BiogenLHI**

ICU, intensive care unit.

Audience Question: How many patients with LHI do you typically see per month?



Please go to **Slido.com** to participate in the audience response questions

- Event code: **BiogenLHI**

LHI, large hemispheric infarction.



THE CASE OF MS. S^a

- Ms. S, 59 years old, is a mother of 2 children and grandmother of 3 children, with a history of atherosclerosis
- On Monday afternoon, she was at the park with her grandchildren when she noticed she was having trouble seeing clearly
- She also noticed some weakness on her right side but was unconcerned and continued on with her daily activities
- 4 hours later, Ms. S's son came over to pick up his kids and noticed that Ms. S had paralysis in her right arm and on the right side of her face and was having difficulty communicating
- Ms. S's son immediately dialed 9-1-1

^aThe case study described here and throughout the presentation is a single ideal patient case study that is based on multiple real-life patients from the presenters' clinical experience.



FUNDAMENTALS OF LHI AND ASSOCIATED LIFE-THREATENING EDEMA

Speaker: Sean I. Savitz, MD

LHI IS ONE OF THE MOST DEVASTATING FORMS OF ACUTE ISCHEMIC STROKE¹

Constitutes ~14% of all strokes²



Source is almost exclusively cardioembolic⁴



Has an annual incidence of 10-20 per 100,000 people³ and a mortality rate of up to 80%¹

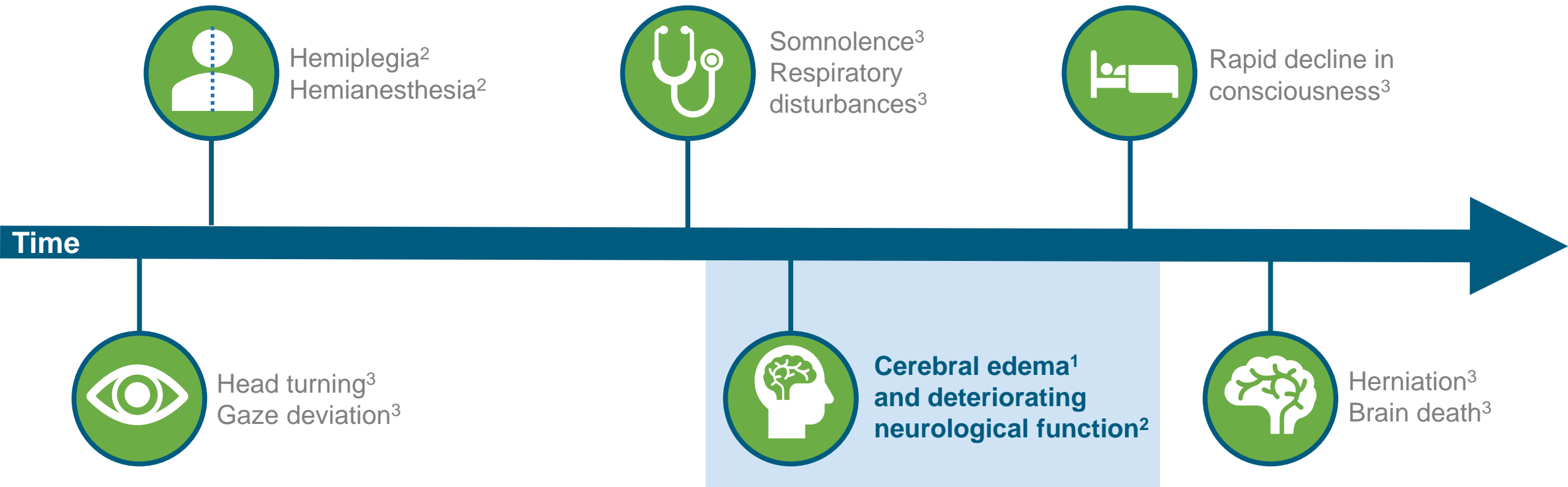
Is a malignant infarction caused by an occlusion that can affect the entire territory of the middle cerebral artery⁵

- At least partially involves the basal ganglia

LHI, large hemispheric infarction.

1. Treadwell and Thanvi. *Postgrad Med J*. 2010;86:235-242. 2. Remedy Pharmaceuticals. White Paper: A Guide to Understanding Large Hemispheric Infarction. 2016. <http://www.remedypharma.com/uploads/7/1/7/3/71731607/lhi.whitepaper.3jun16.pdf>. 3. Heiss. *Cerebrovasc Dis*. 2016;41:1-7. 4. Subramaniam and Hill. *Neurologist*. 2005;11:150-160. 5. Torbey et al. *Neurocrit Care*. 2015;22:146-164.

LHI IS DEFINED BY VARIOUS CLINICAL FEATURES¹

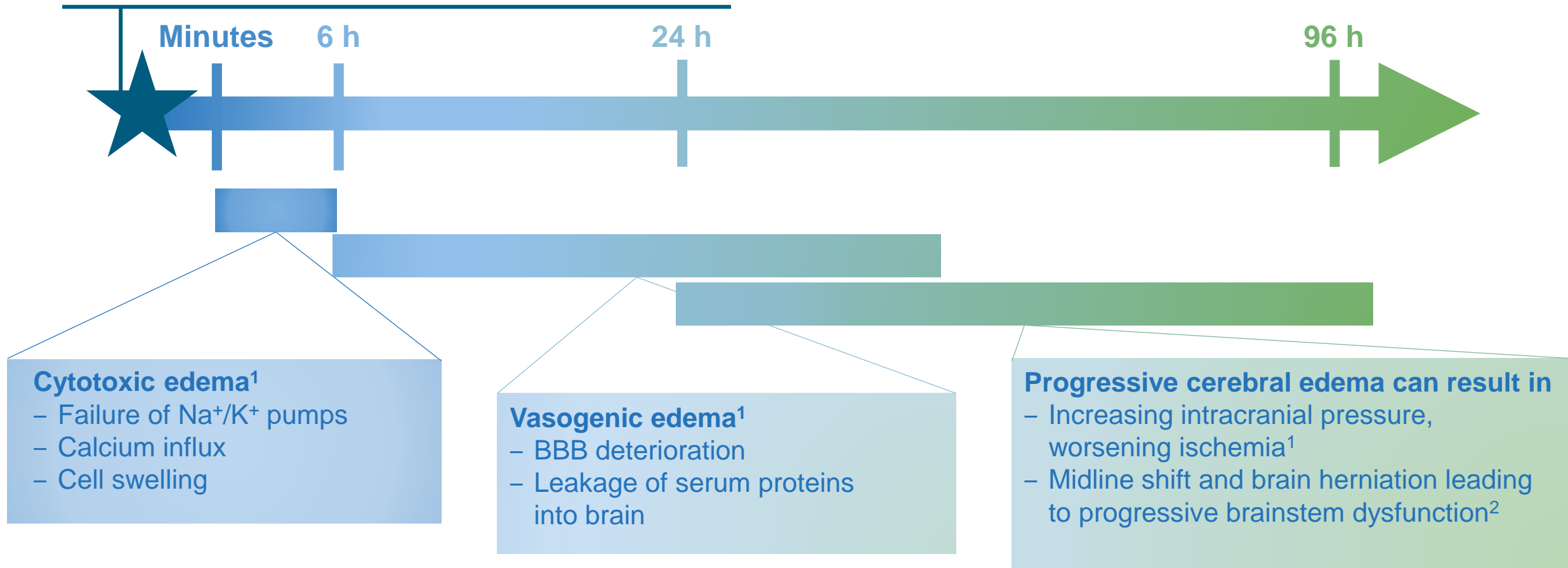


LHI, large hemispheric infarction.

1. Treadwell and Thanvi. *Postgrad Med J.* 2010;86:235-242. 2. Kimberly and Sheth. *Neurol Clin Pract.* 2011;76(7 suppl 2):S50-S56. 3. Steiner et al. *Neurology.* 2001;57:S61-S68.

CEREBRAL EDEMA MAY PROGRESS OVER TIME AS THE PATIENT PROGRESSES TO LHI

Ischemic injury and large-vessel occlusion: Reduced cerebral blood flow¹



BBB, blood-brain barrier; LHI, large hemispheric infarction.

1. Heiss. *Cerebrovasc Dis.* 2016;41:1-7. 2. Treadwell and Thanvi. *Postgrad Med J.* 2010;86:235-242.

STROKE SOCIETIES PROVIDE GUIDELINES FOR MANAGEMENT OF AIS, LHI, AND CEREBRAL EDEMA^{1,2}

Available guidelines are based
largely on expert experience^{1,2}

Management of AIS¹ and
cerebral edema³

AHA/ASA

Management
of LHI²

NCS and German Society
for Neuro-Intensive Care
and Emergency Care

Guidelines emphasize the need for early diagnosis¹

AHA, American Heart Association; AIS, acute ischemic stroke; ASA, American Stroke Association; LHI, large hemispheric infarction; NCS, Neurocritical Care Society.

1. Powers et al. *Stroke*. 2018;49:e46-e110. 2. Torbey et al. *Neurocrit Care*. 2015;22:146-164. 3. Wijdicks et al. *Stroke*. 2014;45:1222-1238.

INITIAL ASSESSMENT AND DIAGNOSTIC WORKUP

Speaker: Jeffrey L. Saver, MD, FAHA, FAAN, FANA

SEVERAL APPROACHES FACILITATE ASSESSMENT OF PROGRESSION TO LHI

The neurological exam and various neuroimaging methods provide a range of information^{1,2}



Neurological
Exam



Neuroimaging

LHI, large hemispheric infarction.

1. Powers et al. *Stroke*. 2018;49:e46-e110. 2. Birenbaum et al. *West J Emerg Med*. 2011;12:67-76.



EARLY ASSESSMENT OF NEUROLOGICAL FUNCTION GUIDES NEXT STEPS¹

**Standardized scales can be used to
assess LHI progression and guide
treatment initiation^{1,2}**

**NIHSS: Most widely used for initial
stroke assessments²**




Dominant severe
hemispheric infarctions³

NIHSS score >20


Nondominant severe
hemispheric infarctions³

NIHSS score >15

**Visual disturbance, aphasia, and neglect are
also important clinical markers⁴**

LHI, large hemispheric infarction; NIHSS, National Institutes of Health Stroke Scale.

1. Powers et al. *Stroke*. 2018;49:e46-e110. 2. Kasner. *Lancet Neurol*. 2006;5:603-612.
3. Kimberly and Sheth. *Neurol Clin Pract*. 2011;76(7 suppl 2):S50-S56. 4. Teleb et al.
J NeuroIntervent Surg. 2017;9:122-126.

THE CASE OF MS. S: USING IMAGING TO FACILITATE DIAGNOSIS



- Ms. S was taken to the ER following her aphasia and right-sided paralysis

Next Steps

- Upon initial evaluation of Ms. S, Dr. Smith noticed gaze deviation, global aphasia, and hemiparesis
- Dr. Smith's notes indicate
 - NIHSS score of 22
 - Global left hemisphere syndrome
 - Time last known well, 4 hours ago

Audience Question: The first imaging procedure you perform is NCCT. What imaging would you perform next?

CTA, computed tomography angiography; CTP, computed tomography perfusion; ER, emergency room; MRI, magnetic resonance imaging; NCCT, noncontrast computed tomography; NIHSS, National Institutes of Health Stroke Scale.



NEUROIMAGING PROVIDES VALUABLE INFORMATION FOR NEXT STEPS

**Imaging is an important aspect
of the evaluation of patients with
stroke and possible progression
to LHI**

Noncontrast computed tomography

Computed tomography angiography

Computed tomography perfusion

Diffusion-weighted MRI

Magnetic resonance angiography

Perfusion-weighted MRI

Cerebral angiography

DW-MRI, diffusion-weighted magnetic resonance imaging; MRI, magnetic resonance imaging.

Birenbaum et al. *West J Emerg Med.* 2011;12:67-76.

PREDICTORS OF CEREBRAL EDEMA AND POOR OUTCOME FOLLOWING ISCHEMIC STROKE

Neurological exam and imaging can reveal features associated with increased risk of developing LHI



High NIHSS score¹

Depressed level of consciousness²

Unilateral or bilateral pupillary dilation¹

Early nausea and vomiting²



Early ischemic change on CT affecting >50% of MCA territory²

>145 mL lesion volume on DW-MRI³

Infarct volume >220 mL on CT³

ASPECT score ≤ 7 ³

ASPECT, Alberta Stroke Program Early CT; CT, computed tomography; DW-MRI, diffusion-weighted magnetic resonance imaging; LHI, large hemispheric infarction; MCA, middle cerebral artery; NIHSS, National Institutes of Health Stroke Scale.

1. Kimberly and Sheth. *Neurol Clin Pract.* 2011;76(7 suppl 2):S50-S56. 2. Treadwell and Thanvi. *Postgrad Med J.* 2010;86:235-242. 3. Heiss. *Cerebrovasc Dis.* 2016;41:1-7.

MANAGEMENT STRATEGIES

Speaker: Tudor G. Jovin, MD

GUIDELINES EMPHASIZE PROMPT TREATMENT¹

Guidelines recommend therapies for AIS, LHI, and associated edema¹⁻³

Management of AIS¹ and
cerebral edema³

AHA/ASA

Management
of LHI²

NCS and German Society
for Neuro-Intensive Care
and Emergency Care

Prompt treatment is important to minimize
long-term disability and impairment⁴

AHA, American Heart Association; AIS, acute ischemic stroke; ASA, American Stroke Association; LHI, large hemispheric infarction; NCS, Neurocritical Care Society.

1. Powers et al. *Stroke*. 2018;49:e46-e110. 2. Torbey et al. *Neurocrit Care*. 2015;22:146-164. 3. Wijdevicks et al. *Stroke*. 2014;45:1222-1238. 4. Roth. *Proc (Bayl Univ Med Cent)*. 2011;24:257-259.

BIOCHEMICAL TESTS CAN IDENTIFY CLINICAL PARAMETERS THAT SHOULD BE MANAGED AFTER STROKE

Biochemical tests can identify parameters associated with unfavorable outcomes after acute ischemic stroke to aid in initial treatment selection

Blood glucose

Oxygen saturation

Renal function

Troponin levels

Complete blood count

Cardiac markers

Prothrombin time

International normalized ratio

Activated partial thromboplastin time

Sodium levels

LHI, large hemispheric infarction.

Jauch et al. *Stroke*. 2013;44:870-947.

THE GOAL IN SEVERE STROKE IS TO PREVENT PROGRESSION FROM LVO TO LHI

Reperfusion strategies aim to maximize the probability of good functional clinical outcomes^{1,2}



rt-PA: Beneficial in patients presenting within ≤ 4.5 hours of symptom onset¹

Thrombectomy: Treatment window may be extended to 24 hours³

LHI, large hemispheric infarction; LVO, large vessel occlusion; rt-PA, recombinant tissue plasminogen activator.

1. Powers et al. *Stroke*. 2018;49:e46-e110. 2. Jauch et al. *Stroke*. 2013;44:870-947.

3. Nogueira et al. *N Engl J Med*. 2018;378:11-21.

THE CASE OF MS. S: MANAGING PATIENT AFTER ADMISSION TO ICU



- Dr. Smith noted that Ms. S displayed global left hemisphere syndrome and had an NIHSS score of 22

Next Steps

- 8 hours after hospital admission and 12 hours after initial onset of symptoms, Dr. Smith performed thrombectomy on Ms. S
- Dr. Smith noted TICl 2B and BP 192/108 and had Ms. S admitted to the ICU, where her BP was controlled
- Upon re-examination of Ms. S, Dr. Smith noted the following:
 - Stable NIHSS score of 20
 - CT shows large infarct but no bleeding or MLS
 - Ms. S is euvolemic, with Na⁺ levels at 138
 - IVC is noncollapsing, CVP = 7 mm Hg
 - Temperature is 37.7° C
 - Blood glucose is 160 mg/dL

Audience Question: Which of the following orders is your next priority?

BP, blood pressure; CT, computed tomography; CVP, central venous pressure; ICU, intensive care unit; IV, intravenous; IVC, inferior vena cava; MLS, midline shift; NIHSS, National Institutes of Health Stroke Scale; TICl, thrombolysis in cerebral infarction.

GENERAL MEASURES AIM TO REDUCE SYSTEMIC COMPLICATIONS¹

Clinicians may use a variety of approaches to reduce systemic complications, including cerebral edema¹

Control of fever¹

Maintenance of normoglycemia¹

Head elevation¹

Maintenance of normovolemia¹

Blood pressure management¹

Supportive clinical evidence is limited²

1. Subramaniam and Hill. *Neurologist*. 2005;11:150-160. 2. Jauch et al. *Stroke*. 2013;44:870-947.

EARLY MEDICAL MANAGEMENT SHOULD FOCUS ON PREVENTING EDEMA AND INCREASES IN ICP¹

Methods of reducing ICP differ in their mechanism of action

Osmotherapy	Hyperventilation	Barbiturates	Anti-edema Therapy
<p>Creates an osmotic gradient across the BBB¹</p> <p><i>Mannitol and hypertonic saline are commonly used²</i></p>	<p>Induces hypocarbia²</p>	<p>Lowers cerebral metabolic activity²</p>	<p>Various mechanisms of action, including some (eg, SUR1 inhibition³) currently under investigation</p>
Choice of methods is based on patient symptoms ⁴			

BBB, blood-brain barrier; ICP, intracranial pressure; SUR1, sulfonylurea receptor 1.

1. Subramaniam and Hill. *Neurologist*. 2005;11:150-160. 2. Treadwell and Thanvi. *Postgrad Med J*. 2010;86:235-242. 3. Sheth et al. *Lancet Neurol*. 2016;15:1160-1169. 4. Simard et al. *Curr Treat Options Neurol*. 2011;13:217-229.

THE CASE OF MS. S: CONSIDERING CRITERIA FOR HEMICRANIECTOMY



- Several general measures were taken to control Ms. S's BP and fluid levels, and her NIHSS score was stable going into her neurology consultation

Next Steps

- During the consultation, the neurosurgeon noted the following:
 - E3 M6 V4 but aphasic with R neglect and RHH
 - Flaccid R hemiplegia, normal LUE tone, and shows 2 fingers
- Ms. S's family hears Dr. Smith consulting with the neurosurgeon and wants to understand what "hemicraniectomy" means, including the potential risks and benefits

Audience Question: What would be an appropriate trigger for a hemicraniectomy?

BP, blood pressure; E, eye opening; LUE, left upper extremity; M, motor response; NIHSS, National Institutes of Health Stroke Scale; R, right side; RHH, right homonymous hemianopia; V, verbal response.

DECOMPRESSIVE SURGERY MAY RELIEVE HIGH ICP ASSOCIATED WITH CEREBRAL EDEMA

The decision to perform a hemicraniectomy requires assessment of multiple factors



Potential benefit¹

- Increasing the likelihood of survival
- Increases likelihood of favorable functional outcome



Timing of possible procedure

- Within 24-48 h of stroke onset but prior to herniation symptoms²



Potential risks include²

- Disability and functional dependency
- Pain, infection, bleeding, and fluid collection



Individual patient characteristics, including²

- Patient age
- Dominant vs nondominant hemisphere involvement

ICP, intracranial pressure.

1. Vahedi et al. *Lancet Neurol.* 2007;6:215-222. 2. Torbey et al. *Neurocrit Care.* 2015;22:146-164.

MONITORING TOOLS

Speaker: Stephan A. Mayer, MD, FCCM

THE CLINICAL EXAM IS RECOMMENDED TO MONITOR DISEASE PROGRESSION IN PATIENTS WITH LHI¹

Scales allow objective measurement of changing clinical status¹

National Institutes of Health Stroke Scale

Provides a quantitative measure of key components of a standard neurological exam²

Glasgow Coma Scale

Measures best eye, motor, and verbal response to assess levels of consciousness³

Oculomotor Exam

Identifies impaired visual function⁴



Important note: Oversedation can cause these types of clinical changes to be missed

LHI, large hemispheric infarction.

1. Powers et al [Erratum appears in *Stroke*. 2018;49:e128]. *Stroke*. 2018;49:e46-e110. 2. Kasner. *Lancet Neurol*. 2006;5:603-612. 3. Weir et al. *Q J Med*. 2003;96:67-74. 4. Rowe. *Brain Behav*. 2017;7:e00771.

THE CASE OF MS. S: NEUROMONITORING CONSULTATION



- Given Ms. S's current stable condition, the neurosurgeon holds off on performing decompressive surgery

Next Steps

- The neurosurgeon and Dr. Smith discuss neuromonitoring options for Ms. S

Audience Question: Neurosurgery asks whether you want an ICP monitor. In addition to the clinical exam, what is your next neuromonitoring plan?

cEEG, continuous electroencephalography; ICP, intracranial pressure; TCD, transcranial Doppler.

MULTIPLE APPROACHES FOR MONITORING DISEASE PROGRESSION

In addition to clinical measures, physicians may use other strategies to monitor

TCD Ultrasonography

Assesses midline shift¹ and offers a minimally invasive alternative to neuroimaging²

ICP Monitors

Measures ICP via ventricular catheters or intraparenchymal/extradural/subdural/subarachnoid probes³

EEG

Helps predict clinical course and estimate prognosis¹

Pupilometer

Evaluates pupil size and reactivity to light⁴

Oxygen Monitoring

Measures partial oxygen pressure of brain tissue⁵

Guidelines for these techniques are generally based on observational evidence¹

CT, computed tomography; EEG, electroencephalogram; ICP, intracranial pressure; LHI, large hemispheric infarction; MRI, magnetic resonance imaging; TCD, transcranial Doppler.

1. Torbey et al. *Neurocrit Care*. 2015;22:146-164. 2. Kilburg et al. *Neurosurg Focus*. 2017;42:E10. 3. Simard et al. *Curr Treat Options Neurol*. 2011;13:217-229. 4. Couret et al. *Critical Care*. 2016;20:99-107. 5. Steiner et al. *Stroke*. 2001;32:2500-2506.

THE CASE OF MS. S: PREPARING FOR HEMICRANIECTOMY



- Unfortunately, after her original neurosurgery consultation, Ms. S's condition begins to deteriorate

Next Steps

- Ms. S becomes more lethargic and is barely able to follow commands, and Dr. Smith notes the following:
 - LUE is flexing to midline
 - Left pupil is mid-position but is less reactive than right pupil
- The neurosurgeon is called, and Ms. S is taken to the OR for a hemicraniectomy
- During the post-op examination
 - Post-op CT shows a good surgical result, with restoration of midline structures
 - Ms. S has a stable GCS score of E3 M5 V3 and tolerates CPAP for 8 h

Audience Question: What is the most important next step to minimize postoperative complications and length of stay?

CPAP, continuous positive airway pressure; CT, computed tomography; E, eye opening; GCS, Glasgow Coma Scale; IV, intravenous; IVC, inferior vena cava; LUE, left upper extremity; M, motor response; OR, operating room; V, verbal response.

LOOKING TO THE FUTURE

Speaker: Edward C. Jauch, MD, MS, FAHA

THE CASE OF MS. S: HOSPITAL DISCHARGE AND FOLLOW-UP



- Despite her deteriorating condition, the hemicraniectomy was successful

Next Steps

- Ms. S is discharged from the hospital 12 days after her surgery and is sent to long-term acute care after tracheotomy and PEG
- 3 months after her initial symptoms, Ms. S is doing well
 - At her follow-up, Dr. Smith notes an mRS score of 3
- Ms. S is able to walk with the aid of a cane and is once again able to visit the park with her grandchildren

mRS, modified Rankin Scale; OR, operating room; PEG, percutaneous endoscopic gastrostomy.



In this fictional case study, the patient was able to return home but was not able to resume all of her normal activities

However, there are numerous strategies that should be considered to optimize patient treatment

STRATEGIES FOR THE FUTURE



**Establish Stroke
Protocols for Ground
and Air Transport
Crews¹ and Implement
MSUs²**



**Provide Education and
Protocols to Smaller
Remote Hospitals and
Establish Telestroke¹**



**Develop
Recommendations
for Palliative Care¹**

MSU, mobile stroke unit.

1. Jauch et al. *Stroke*. 2013;44:870-947. 2. Bowry et al. *Stroke*. 2015;46:3370-3374.

CLINICAL TRIALS SEEK TO EVALUATE OPTIONS TO IMPROVE TREATMENT OF STROKE AND/OR LHI

COMPLETED

PLANNED

THROMBECTOMY		DHC		PHARMACOLOGICAL TREATMENTS	
Trials	Objectives	Trials	Objectives	Trials	Objectives
MR CLEAN ¹ (Phase 3) DEFUSE 3 ² (Phase 3) DAWN ^{3,4} (Phase 2/3)	Functional outcomes within different therapeutic windows ¹⁻³	DECIMAL ^{6,7} (Phase 3) DESTINY ^{6,8} (Phase 3) HAMLET ^{6,9} (Phase 3)	Effect of hemicraniectomy on functional outcomes ⁶	GAMES-RP ¹⁰ (Phase 2)	Effects of SUR1 inhibitor on prevention/ treatment of severe cerebral edema following LHI ¹⁰
TENSION ⁵ (Phase 3)	Comparative safety/efficacy vs best medical care alone ⁵			CHARM ¹¹ (Phase 3)	Effects of SUR1 inhibitor on functional outcomes in patients with LHI ¹¹

DHC, decompressive hemicraniectomy; LHI, large hemispheric infarction.

1. Berkhemer et al. *N Engl J Med*. 2015;372:11-20. 2. Albers et al. *Int J Stroke*. 2017;12:896-905. 3. Nogueira et al. *N Engl J Med*. 2018;378:11-21. 4. <https://www.clinicaltrials.gov/ct2/show/NCT02142283>. 5. <https://clinicaltrials.gov/ct2/show/NCT03094715>. 6. Vahedi et al. *Lancet Neurol*. 2007;6:215-222. 7. <https://clinicaltrials.gov/ct2/show/NCT00190203>. 8. <http://www.isrctn.com/ISRCTN01258591>. 9. <http://www.isrctn.com/ISRCTN94237756>. 10. Sheth et al. *Lancet Neurol*. 2016;15:1160-1169. 11. <https://clinicaltrials.gov/ct2/show/NCT02864953>.

SUMMARY

Disease Fundamentals

A large vessel occlusion may progress into a malignant infarction that affects the entire territory of the middle cerebral artery¹

Initial Assessment

The clinical exam and neuroimaging assess patient progression to LHI^{2,3}

Management

Early medical management focuses on preventing edema and increases in ICP⁴

Monitoring

The clinical exam is useful in monitoring disease progression⁵

Expanding access to stroke education and protocols and seeking improved therapy options are additional strategies for patient success⁶

ICP, intracranial pressure; LHI, large hemispheric infarction.

1. Torbey et al. *Neurocrit Care*. 2015;22:146-164. 2. Kasner. *Lancet Neurol*. 2006;5:603-612. 3. Birenbaum et al. *West J Emerg Med*. 2011;12:67-76. 4. Subramaniam and Hill. *Neurologist*. 2005;11:150-160. 5. Powers et al [Erratum appears in *Stroke*. 2018;49:e128]. *Stroke*. 2018;49:e46-e110. 6. Jauch et al. *Stroke*. 2013;44:870-947.

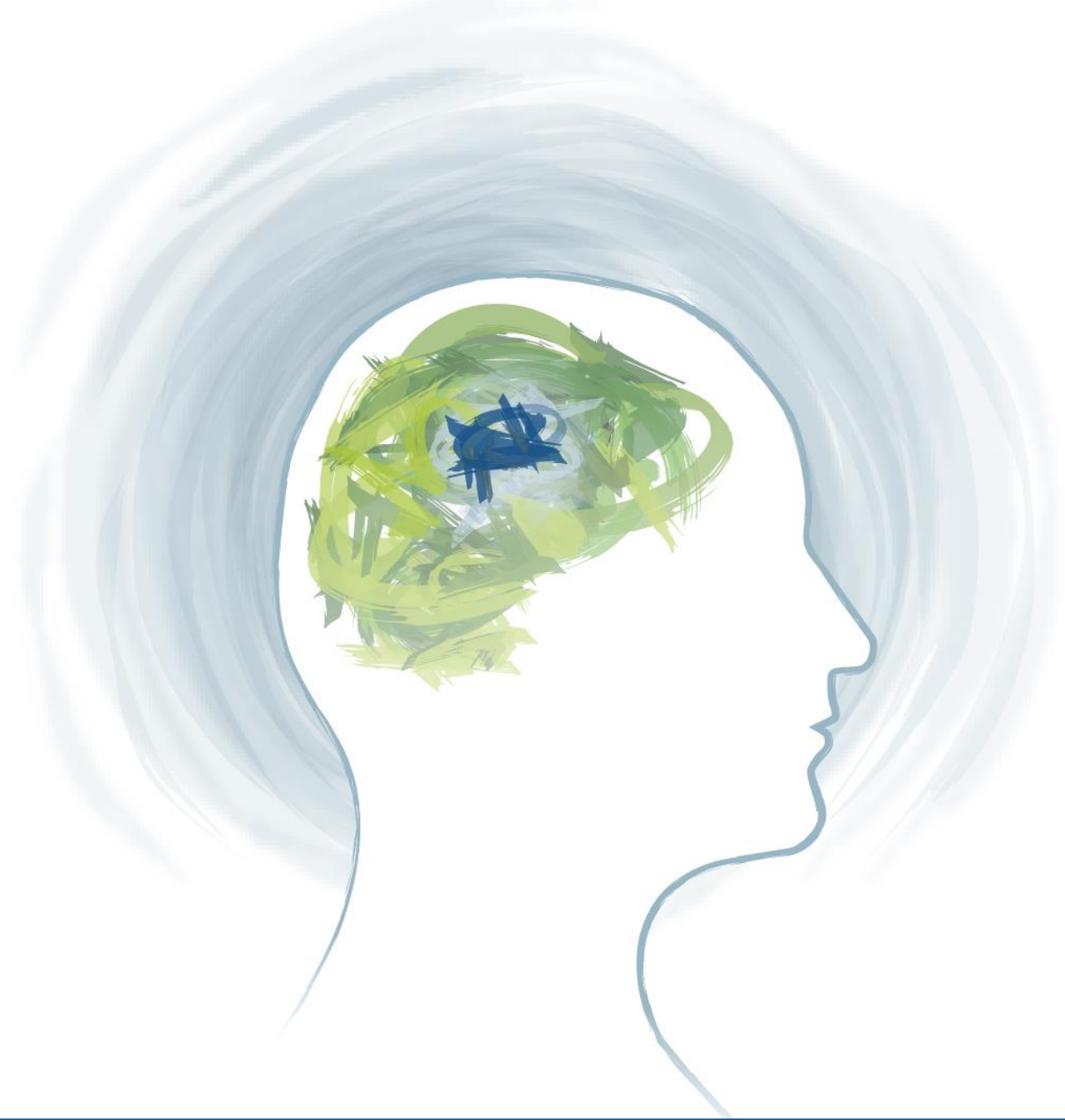
Audience Question: Please rank your agreement with the following statement:
“This symposium has improved my understanding of LHI.”



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LHI, large hemispheric infarction.



FINAL THOUGHTS

Please remember to fill out your evaluation forms. Thank you.