INDIANA UNIVERSITY
SCHOOL OF MEDICINE

Magnetic Resonance Imaging (MRI) Predictors of Surgical Intervention in Acute Mastoiditis

Troy Wesson, BS[1], Jasmine Higgins, MPH[1], William Bennett, MD[1,3], Kris Mosier, MD[1,4], Sarah Burgin, MD[1,2]

[1]Indiana University School of Medicine, [2]Indiana University Department of Otolaryngology-Head and Neck Surgery, [3]Indiana University Department of Pediatrics, [4]Indiana University Department of Radiology

BACKGROUND

- Acute mastoiditis (AM) is the most common complication associated with otitis media in which there is inflammation of the temporal mastoid air cells [1].
- Significant complications beyond the mastoid system can occur, including subperiosteal abscess, meningitis, intracranial thrombus, facial nerve paralysis, and intraparenchymal abscesses [2, 3].
- AM treatment remains variable given that treatment is often based on provider-specific judgment rather than reproducible objective criteria [4].
- Regimens include intravenous antibiotics alone or in combination with surgical approaches including myringotomy, tympanostomy tube placement, or mastoidectomy [4, 5].
- Clinical outcome studies regarding outcomes after non-surgical management of AM are limited by the retrospective nature and biases of participating providers regarding surgical indications.
- This study aims to identify MRI parameters that are associated with surgical intervention in pediatric patients with acute mastoiditis, and to develop an MRI-based predictive model to help decision-making in surgically treating patients with AM.

MATERIALS AND METHODS

Study Design

The Pediatric Health Information System (PHIS), a comparative national database maintained by the Children's Hospital Association, was queried for inpatient stays with a diagnostic code of mastoiditis (ICD-9 38.XX and ICD-10 H70.XX between January 1st 2000 and January 31st, 2019). The medical records of these patients were manually reviewed. There were 62 pediatric patients identified. Of these, 29/62 (46.8%) had bilateral mastoiditis, which resulted in 91 ears for evaluation. Of these, 11 were excluded due to history of either cholesteatoma or prior mastoidectomy.

Imaging Analysis

MRI parameters were obtained by two authors (TW and JH) on a workstation with Synapse: sigmoid sinus thrombus, internal jugular vein thrombus, transverse sinus thrombus, cavernous sinus thrombus, subperiosteal abscess, neck abscess, intraparenchymal abscess, epidural abscess, mastoid cell enhancement, mastoid cell osteomyelitis, petrous apex osteomyelitis, cortical bone osteomyelitis, dural/leptomeningeal enhancement, dural thickening (<1 mm, 1-3 mm, >3 mm), and mastoid opacification (partial or complete). Imaging was reviewed a second time by a board-certified neuroradiologist (KM) as well as a board-certified otolaryngology head & neck surgeon (SB), both blinded to the clinical outcome of the patients. In addition, diffusion weighted images were obtained by KM for a subset of the cases at either 1.5T or 3T using single shot echo-planar DWI with maximum b-value of 1000 s/mm^2 and in several cases trace images. Uniform regions of interest (ROI) were placed on the mastoid and the contralateral medulla and the mean DWI, and ADC recorded. The lesion to ADC ratio was recorded to normalize measurements across systems and variations in pneumatization of the mastoid and petrous apex.

Statistical Analysis

Univariate analysis was performed and significant variables were used in a binary logistic regression model. The prediction models were built by using multiple binary regression analysis and the performance of the models was assessed through determination of sensitivity and specificity as well as the area under the curve (AUC) in the receiver operating characteristic curve (ROC).

RESULTS

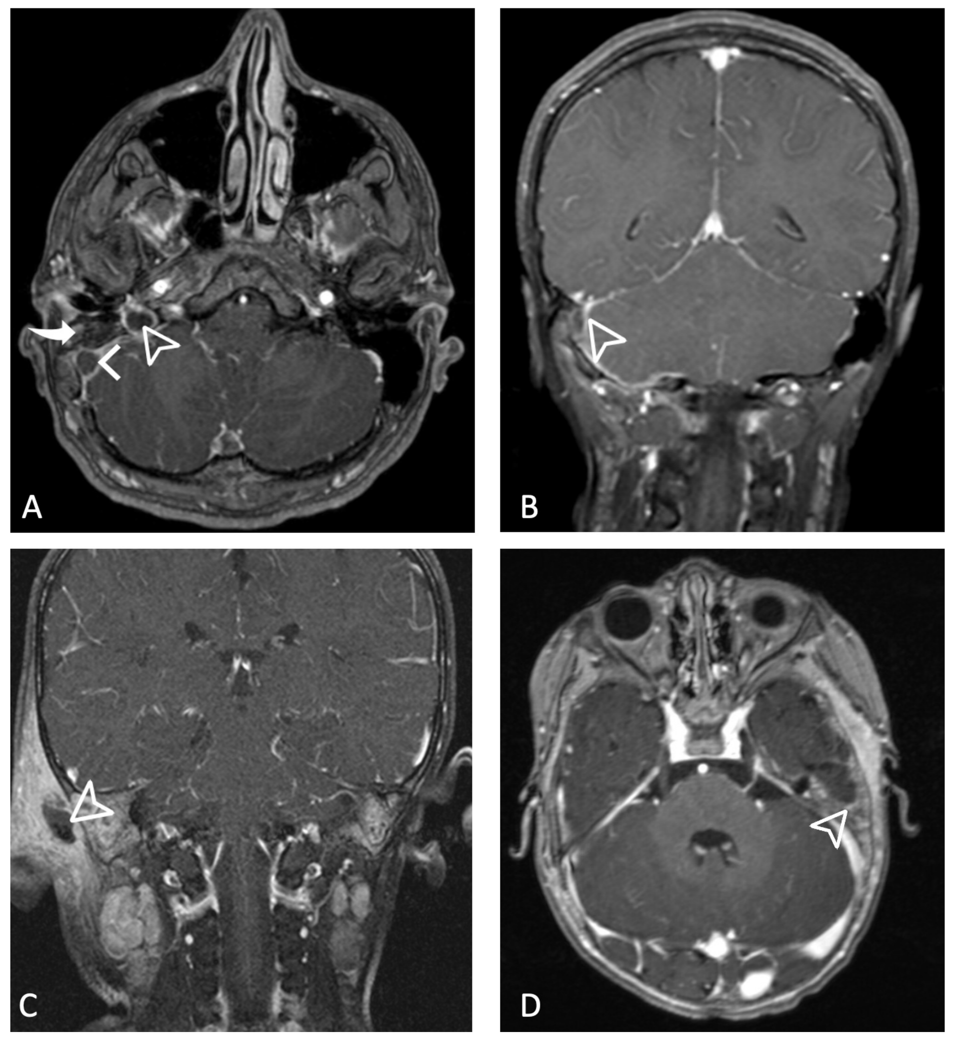

Figure 1. (**A**) Axial contrast enhanced T1 weighted image with fat saturation shows loss of central luminal contrast representing thrombus in the jugular bulb (arrowhead) and the sigmoid sinus (short arrow). There is mild focal enhancement of the mastoid (curved arrow). (**B**) Coronal contrast enhanced T1 SE+C showing pechymeningeal/dural enhancement (arrowhead) adjacent to the sigmoid sinus which shows a flow void consistent with a thrombus. (**C**) Coronal contrast enhanced T1 weighted image showing extensive enhancement of the subperiosteal space with a large non-enhancing subperiosteal abscess (arrowhead). (**D**) Axial contrast enhanced T1 weighted image IRSPGR showing marked marrow space enhancement of temporal bone consistent with osteomyelitis (arrowhead).

	All	Non-Surgical	Surgical
1. Dural Enhancement			
Absent, N (%)	48 (68.6%)	32 (84.2%)	16 (50%)
Present, N (%)	22 (31.4%)	6 (15.8%)	16 (50%)
2. Sigmoid Sinus Thrombus			
Absent, N (%)	61 (87.1%)	36 (94.7%)	25 (78.1%)
Present, N (%)	9 (12.9%)	2 (5.3%)	7 (21.9%)
3. Internal Jugular Vein Thrombus			
Absent, N (%)	61 (87.1%)	37 (97.4%)	24 (75%)
Present, N (%)	9 (12.9%)	1 (2.6%)	8 (25%)
4. Transverse Sinus Thrombus			
Absent, N (%)	64 (91.4%)	37 (97.4%)	27 (84.4%)
Present, N (%)	6 (8.6%)	1 (2.6%)	5 (15.6%)
5. Cavernous Sinus Thrombus			
Absent, N (%)	70 (100%)	38 (100%)	32 (100%)
Present, N (%)	0 (0%)	0 (0%)	0 (0%)
6. Venous Thrombus			
Absent, N (%)	46 (65.7%)	34 (89.5%)	12 (60.0%)
Present, N (%)	24 (34.3%)	4 (10.5%)	8 (40.0%)
6. Subperiosteal Abscess			
Absent, N (%)	69 (86.2%)	46 (97.9%)	23 (69.7%)
Present, N (%)	11 (13.8%)	1 (2.1%)	10 (30.3%)
7. Neck Abscess			
Absent, N (%)	80 (100%)	47 (100%)	33 (100%)
Present, N (%)	0 (0%)	0 (0%)	0 (0%)
8. Intraparenchymal Abscess			
Absent, N (%)	79 (98.7%)	47 (100%)	32 (97%)
Present, N (%)	1 (1.3%)	0 (0%)	1 (3%)
9. Epidural Abscess			
Absent, N (%)	73 (91.2%)	45 (95.7%)	28 (84.8%)
Present, N (%)	7 (8.8%)	2 (4.3%)	5 (15.2%)
10. Mastoid Enhancement			
Absent, N (%)	6 (8.6%)	4 (10.5%)	2 (6.3%)
Mild-to-Moderate, N (%)	47 (67.1%)	24 (63.2%)	23 (71.9%)
Significant, N (%)	17 (24.3%)	10 (26.3%)	7 (21.8%)
11. Mastoid Osteomyelitis			
Absent, N(%)	80 (100%)	47 (100%)	33 (100%)
Present, N (%)	0 (0%)	0 (0%)	0 (0%)
12. Petrous Apex Osteomyelitis			
Absent, N (%)	79 (98.7%)	47 (100%)	32 (96.9%)
Present, N (%)	1 (1.3%)	0 (0%)	1 (3.1%)
13. Cortical Bone Osteomyelitis			
Absent, N (%)	76 (95%)	44 (93.6%)	32 (97%)
Present, N (%)	4 (5%)	3 (6.4%)	1 (3%)
14. Dural Thickening			
Absent, N (%)	48 (68.6%)	31 (81.6%)	17 (53.1%)
<1 mm, N (%)	8 (11.4%)	3 (7.9%)	5 (15.6%)
1-3 mm, N (%)	11 (15.7%)	3 (7.9%)	8 (25%)
>3 mm, N (%)	3 (4.3%)	1 (2.6%)	2 (6.3%)
15. Mastoid Opacification			
Absent, N (%)	1 (1.2%)	0 (0%)	1 (3%)
Partial (<80%), N (%)	21 (26.3%)	9 (19.1%)	12 (36.4%)
Complete (>80%), N (%)	58 (72.5%)	38 (80.9%)	20 (60.6%)

Table 1. Prevalence of head MRI findings based on treatment modality (surgical vs non-surgical treatment) for 80 patients except for dural enhancement, sigmoid sinus thrombus, internal jugular vein thrombus, transverse sinus thrombus, cavernous sinus thrombus, venous thrombus, dural enhancement, dural thickening, and mastoid enhancement where only 70 patients' data were available.

Variable Name	Subcategories	N	χ^2	df	Pearson Coefficient	P value
Mean (US) DWI			N/A		-0.080[b]	0.658[a]
Mean (US) ADC			N/A		0.227[b]	0.297[a]
DWI Ratio			N/A		0.153[b]	0.396[a]
Dural Enhancement		22	11.727	1	N/A	**<0.001***
Sigmoid Sinus Thrombus		9	N/A		N/A	0.070[c]
Internal Jugular Vein Thrombus		9	N/A		N/A	**0.009***
Transverse Sinus Thrombus		6	N/A		N/A	0.083
Cavernous Sinus Thrombus		0	N/A		N/A	N/A
Venous Thrombus		10	6.773	1	N/A	**0.009***
Subperiosteal Abscess		11	N/A		N/A	**<0.001***
Neck Abscess		0	N/A		N/A	N/A
Intraparenchymal Abscess		1	N/A		N/A	0.420
Epidural Abscess		7	N/A		N/A	0.118
Mastoid Enhancement	Mild-to-Moderate Significant	47 17	0.718	2	N/A	0.698
Mastoid Osteomyelitis		0				N/A
Petrous Apex Osteomyelitis		1	N/A		N/A	0.418
Cortical Bone Osteomyelitis		4	N/A		N/A	0.639
Dural Thickening	<1 mm 1-3 mm >3 mm	7 11 3	6.83	3	N/A	0.077
Mastoid Opacification	Partial (<80%) Complete (>80%)	21 59	5.033	2	N/A	0.081

Table 2. Univariate analysis of a list of 19 variables comparing the surgical group with the non-surgical group.

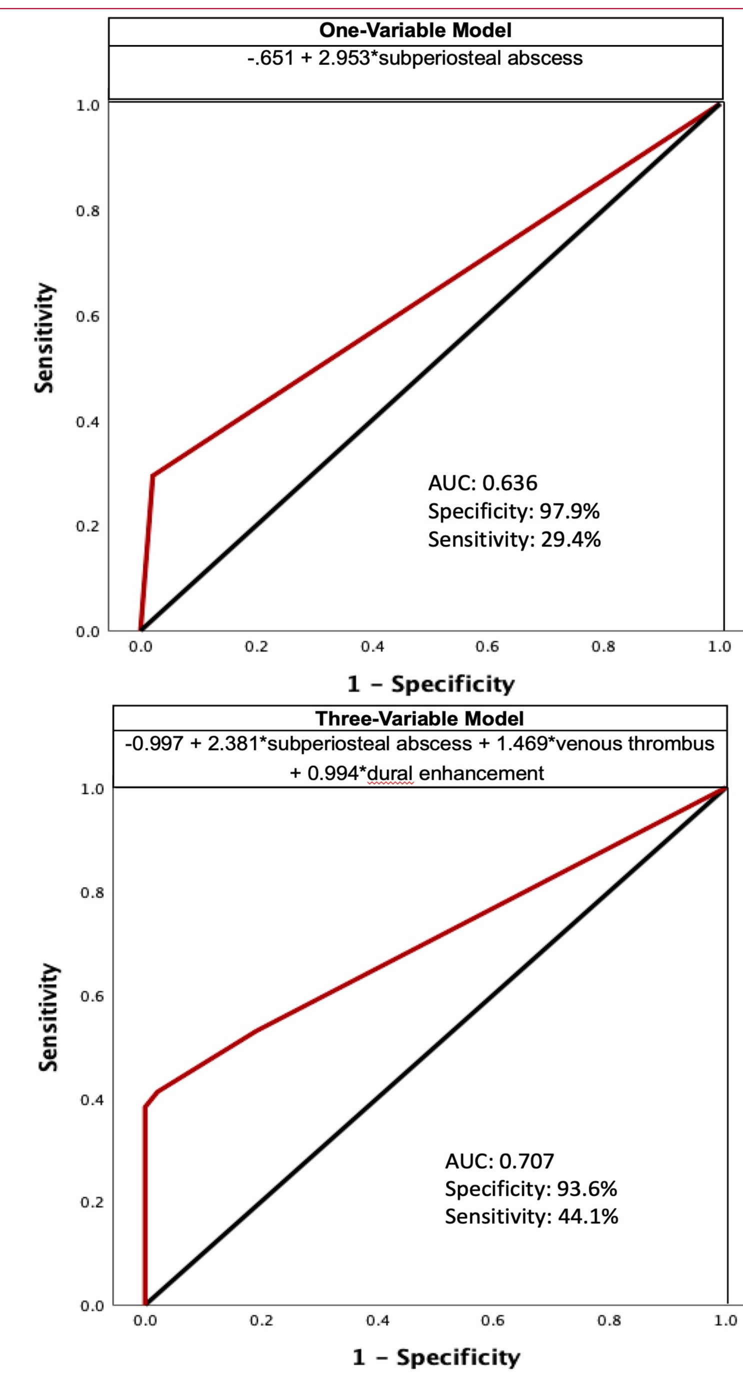

Figure 2. The receiver operating characteristic (ROC) curve of both the one-variable model and the three-variable model. The red line represents the model-specific curve. The black line serves as a reference line, since it is the ROC curve of a random classification. A perfect test has an area under the curve (AUC) of 1.

DISCUSSION

- The improved sensitivity of MRI for the detection of abscesses and intracranial pathology in comparison to CT scan makes it an ideal imaging modality when there is concern for complications of AM [6].
- To our knowledge, there has not been a comprehensive assessment of imaging findings and their role in guiding surgical intervention in these patients.
- Our findings show that intracranial thrombus, dural enhancement, and subperiosteal abscess are associated with surgery in AM. Based on this acquired data, we produced two separate predictive models for surgery. We proceeded to use sensitivity, specificity, and ROC curve to compare the diagnostic performance of the two models generated.
- The three-variable model (venous thrombus, dural enhancement, and subperiosteal abscess) is multifaceted, however it has the benefit of offering a higher sensitivity than the one-variable model (44.1% vs 29.4%). On the contrary, the one-variable model (subperiosteal abscess) is more straightforward and can be easily obtained without contrast studies.
- Based on standing classifying systems for interpretation of area under the curve (AUC), the value obtained for the three-variable model (0.707) should be interpreted as a "fair" predictive test [7]. The one-variable model falls under the category of "poor" with an AUC value of 0.63 [7].
- Future studies should further assess the predictive value of the two models in a prospective manner to quantify disease severity

CONCLUSION

Head MRI findings of abscess formation, dural enhancement, and intracranial thrombus were found to be associated with surgery in pediatric patients with acute mastoiditis. The introduction of two models using retrospective data is the first step towards the development of a system for quantifying disease severity in pediatric patients with AM.

REFERENCES

[1] Cassano, P., G. Ciprandi, and D. Passali, *Acute mastoiditis in children.* Acta Biomed, 2020. **91**(1-S): p. 54-59.

[2] Mustafa, A., et al., *Treatment of acute mastoiditis: report of 31 cases over a ten year period.* Rev Laryngol Otol Rhinol (Bord), 2004. **125**(3): p. 165-9.

[3] Glynn, F., et al., *Acute mastoiditis in children: presentation and long term consequences.* J Laryngol Otol, 2008. **122**(3): p. 233-7.

[4] Kaufmann, M.R., et al., *Management of Acute Complicated Mastoiditis: A Systematic Review and Meta-analysis.* Pediatr Infect Dis J, 2022. **41**(4): p. 297-301.

[5] Anne, S., et al., *Medical Versus Surgical Treatment of Pediatric Acute Mastoiditis: A Systematic Review.* Laryngoscope, 2019. **129**(3): p. 754-760.

[6] Unal, O., et al., *The diagnostic value of diffusion-weighted magnetic resonance imaging in soft tissue abscesses.* Eur J Radiol, 2011. **77**(3): p. 490-4.

[7] Nahm, F.S., *Receiver operating characteristic curve: overview and practical use for clinicians.* Korean J Anesthesiol, 2022. **75**(1): p. 25-36.