Pseudomeningocele and CSF leak following posterior fossa and posterolateral skull base surgeries: Development of a predictive model and risk score

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Disclosure

- No disclosures
- No conflicts of interest

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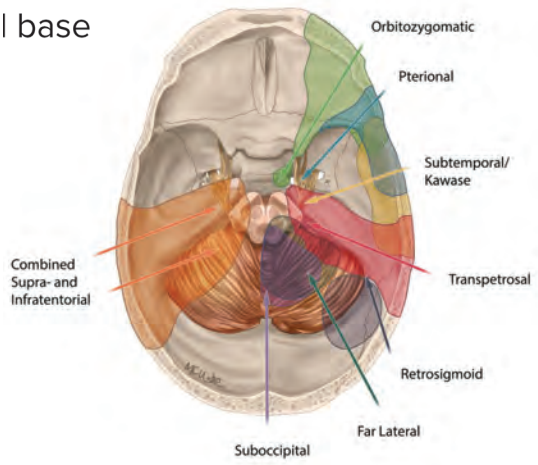
Background

- Indications for posterolateral skull base and posterior fossa procedures:
  - Tumors
  - Cysts
  - Aneurysms
  - Nerve compression
  - Congenital malformations
  - Arteriovenous malformation
  - Cranial nerve compression



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Background

- Incidence of post-op supratentorial CSF leaks: 1–11% [1]
- Incidence of post-op infratentorial CSF leaks: **13–35%** [2,3]

- "CSF leaks vary so much in degree and cause that each is a special problem unto itself."

  – Harvey Cushing, 1909 [4]

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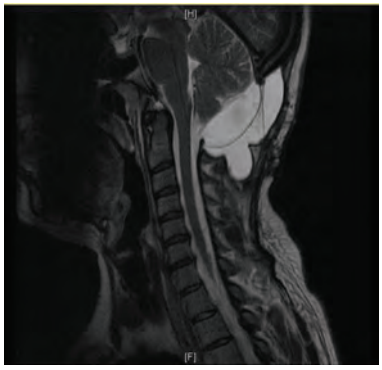
Background

- CSF leak associated with:
  - Meningitis / encephalitis
  - Subdural hematoma
  - Pneumocephalus
  - Need for revision
  - Prolonged hospital stay



Case courtesy of Radiopaedia.org
Radiopaedia ID: 11828

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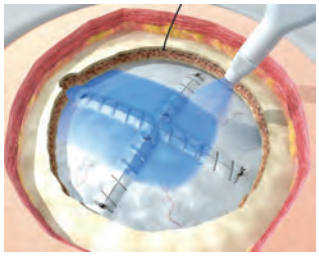
Background

- Techniques for preventing CSF leak:
  - Use of dural sealants
  - Primary closure vs fat grafting vs synthetics
  - Autologous pericranium or fascia
  - Bone flap replacement vs bone substitute



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Objectives

- Identify risk factors for CSF-related complications following posterior fossa and skull base procedures
- Develop a risk score that predicts whether a patient will develop postoperative CSF-related complications

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Methods – Study design

- Single-institution retrospective review
- Posterolateral skull base or posterior fossa procedures
- January 2016 to January 2020
- Excluded:
  - Procedures without intracranial components
  - Procedures including nasal endoscopy
  - Anterior fossa procedures
  - Surgical indication for spontaneous CSF leak
  - ENT-only procedures

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Methods – Outcome variable

- YES or NO, did the patient develop a post-operative CSF-related complication (POCC)?
- Inclusion criteria for POCC:
  - Pseudomeningocele (fluid on MRI/CT > 48 hours post-op)
  - Any evidence of CSF drainage
  - Incisional leak
- Exclusion criteria:
  - Wound infections

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Results

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POCC characteristics

- **Incidence of POCC** = 115 out of 450 patients (25.6%)
- **Median time to POCC** = 22 days (IQR: 13–47 days)

Table 1. Management of POCC

POCC management	Count (n=115)
Conservative management	34 (29.6%)
Wound revision	15 (13.0%)
Bedside aspiration	10 (8.7%)
Bedside aspiration + VP shunt	1 (0.9%)
External ventricular drain (EVD)	7 (6.1%)
EVD + VP shunt	42 (36.5%)
VP shunt alone	6 (5.2%)

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Table 2. Descriptive statistics

Demographics & Perioperative factors	No CSF-related complications (n=335)	CSF-related complications (n=115)
Demographics		
Mean age in years	55 (SD: 15.6)	47 (SD: 15.3)
Female sex	191 (57%)	67 (58%)
BMI	30.0 (SD: 7.9)	32.0 (SD: 8.2)
Diabetes mellitus	57 (17%)	16 (14%)
Tobacco use	72 (22%)	36 (31%)
History of remote radiation	52 (16%)	13 (11%)
Preoperative management		
Pre-op CSF diversion	30 (9%)	14 (12%)
Pre-op steroid use	59 (18%)	36 (31%)
Pre-op radiation	7 (2%)	5 (4%)
Surgical approach		
Suboccipital	105 (31%)	66 (57%)
Retrosigmoid	98 (29%)	15 (13%)
Translabyrinthine	67 (20%)	5 (4%)
Transpetrosal	40 (12%)	7 (6%)
Transmastoid	8 (2%)	9 (8%)
Far lateral/transcondylar	6 (2%)	9 (8%)

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Table 2. Descriptive statistics (continued)

Demographics & Perioperative factors	No CSF-related complications (n=335)	CSF-related complications (n=115)
Dural repair technique		
Pericranium/fascia	168 (50%)	55 (48%)
Fat graft	94 (28%)	21 (18%)
Synthetic duraplasty	41 (12%)	23 (20%)
Combination	24 (7%)	6 (5%)
Primary closure	8 (2%)	10 (9%)
Bony reconstruction		
Bone substitute	196 (59%)	36 (31%)
Bone flap replacement	33 (10%)	23 (20%)
Bone flap + substitute	38 (11%)	9 (8%)
None	68 (20%)	47 (41%)
Post-operative management		
Post-op steroid use	292 (87%)	104 (90%)
Post-op steroid duration, days	11.6 (SD: 9.9)	15.8 (S: 11.1)
Post-op CSF diversion	53 (16%)	49 (43%)
1–7 days duration	39 (12%)	28 (24%)
> 7 days duration	14 (4%)	21 (18%)
Post-op chemo/radiation	69 (21%)	32 (28%)

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Table 3. Univariate analysis

Demographic and pre-op variables	Odds ratio for CSF-related complication (95% CI)	p-value
Age (reference < 40)		
40–54 years	0.74 (0.43–1.27)	0.28
55–64 years	0.41 (0.22–0.79)	0.007
≥ 65 years	0.32 (0.17–8.43)	0.001
Female sex	1.05 (0.70–1.16)	0.82
BMI		
Underweight	1.74 (0.42–7.25)	0.45
Obese	1.58 (0.88–2.85)	0.12
Morbidly obese	3.15 (1.46–6.75)	0.003
Remote radiation	0.69 (0.36–1.33)	0.27
Diabetes mellitus	0.80 (0.44–1.45)	0.46
Tobacco use	1.65 (1.03–2.66)	0.036
Pre-op CSF diversion	0.71 (0.36–1.39)	0.32
Pre-op steroid use	2.15 (1.32–3.49)	0.02
Pre-op radiation	2.12 (0.66–6.84)	0.20
Tumor volume in cm^3	1.01 (0.99–1.03)	0.058

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Table 3. Univariate analysis (continued)

Intra-op and post-op variables	Odds ratio for CSF-related complication (95% CI)	p-value
Suboccipital approach	2.75 (1.78–4.24)	< 0.001
Lesion location		
Posterior fossa	0.74 (0.18–3.04)	0.68
Skull base	0.57 (0.14–2.40)	0.44
Ventricular violation	1.82 (0.95–3.40)	0.06
Dural repair		
Pericranium/fascia	0.26 (0.10–0.70)	0.007
Synthetic duraplasty	0.45 (0.16–1.30)	0.14
Fat graft	0.18 (0.06–0.51)	0.001
Combination	0.20 (0.06–0.73)	0.014
Use of bone substitute	0.44 (0.28–0.69)	< 0.001
Post-op steroid use	1.39 (0.69–2.80)	0.35
Post-op steroid duration	1.04 (1.02–1.07)	< 0.001
Post-op CSF diversion	3.95 (2.46–6.33)	< 0.001
Post-op CSF diversion duration		
1–7 days	3.16 (1.81–5.51)	< 0.001
> 7 days	6.43 (3.10–13.31)	< 0.001
Post-op chemo/radiation	1.49 (0.91–2.42)	0.11

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Selecting variables for a multivariable model

- **Model 1:** clinical suspicion (literature/anecdotal)
- **Model 2:** univariate odds ratios (≤ 0.5 or ≥ 2.0)
- **Model 3:** univariate odds ratios AND p-values (≤ 0.10)

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Variables included in each multivariable model

Model 1 (*a priori*)	Model 2 (odds ratios)	Model 3 (OR + p-value)
BMI	BMI	BMI
Tobacco use	Tobacco use	Tobacco use
Diabetes	Diabetes	Diabetes
Hx of remote cranial radiation	Hx of remote cranial radiation	Hx of remote cranial radiation
Pre-op cranial radiation	Pre-op cranial radiation	Pre-op cranial radiation
Pre-op steroid use	Pre-op steroid use	Pre-op steroid use
Lesion location	Lesion location	Lesion location
Dural repair technique	Dural repair technique	Dural repair technique
Use of bone substitute	Use of bone substitute	Use of bone substitute
Post-op steroid duration	Post-op steroid duration	Post-op steroid duration
—	**Age**	Age
—	**Suboccipital approach**	Suboccipital approach
—	**Post-op CSF diversion**	Post-op CSF diversion
—	—	**Ventricular violation**

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Model 1 (*a priori*)	Model 2 (odds ratios)	Model 3 (OR + p-value)

How to choose?

Receiver operating characteristic (ROC) curves!

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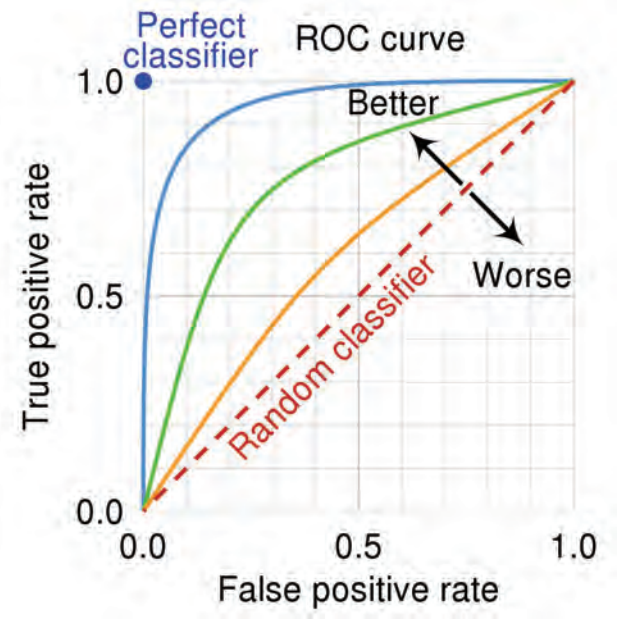

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Figure 1. Cross-validating each multivariable model

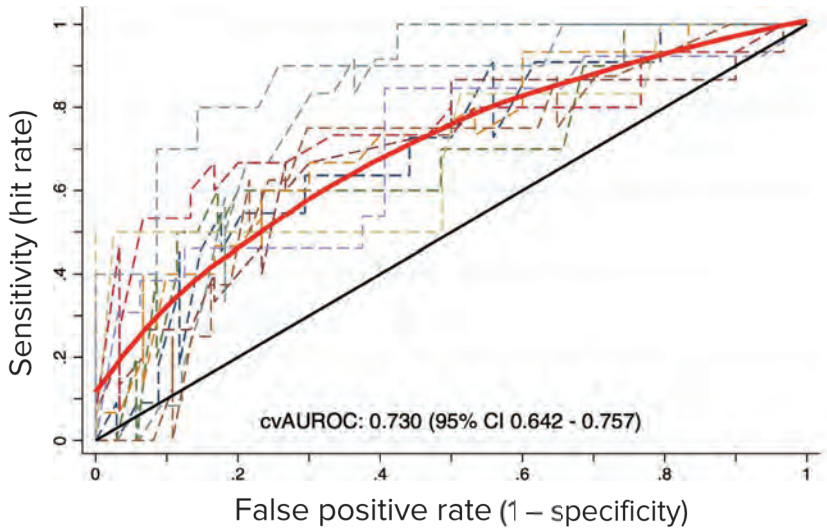

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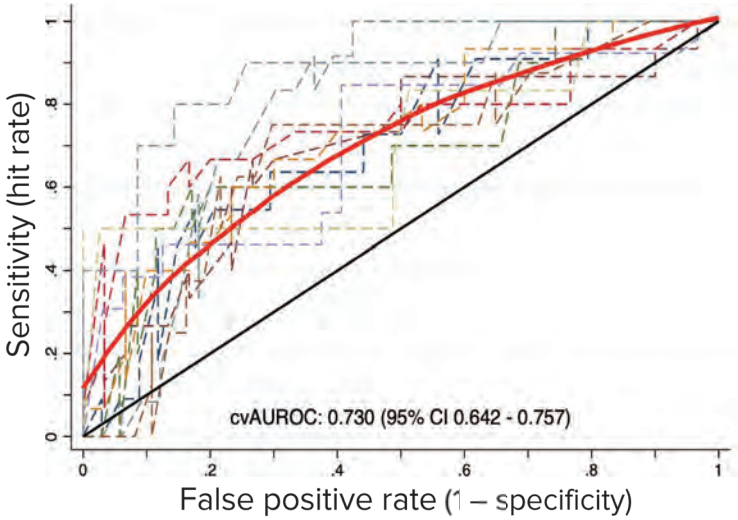
Figure 1. Cross-validating each multivariable model



Area under ROC curve:

- Model 1 = 0.624
- Model 2 = 0.730
- Model 3 = 0.711

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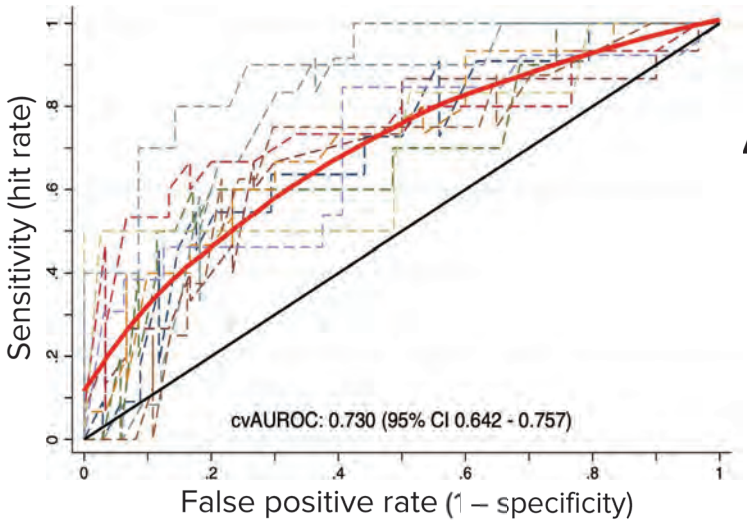
Figure 1. Cross-validating each multivariable model



Area under ROC curve:

- Model 1 = 0.624
- Model 2 = 0.730
- Model 3 = 0.711

Table 4. Preliminary variables for predictive model

Protective factor

Protective factor

Risk factor

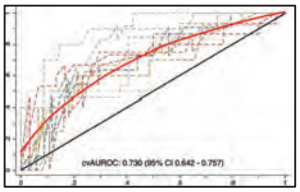
Risk factor

Variable	Odds ratio (95% CI)	p-value
Age > 55 years	0.65 (0.43–0.97)	0.033
BMI > 30	1.61 (1.10–2.34)	0.013
Tobacco use	1.26 (0.84–1.88)	0.256
Diabetes	0.71 (0.41–1.22)	0.217
History of remote radiation	0.98 (0.56–1.70)	0.931
Pre-op radiation	1.00 (0.35–2.85)	0.997
Pre-op steroid use	1.06 (0.65–1.72)	0.843
Lesion location		
Posterior fossa	1.81 (0.56–5.87)	0.320
Skull base	1.53 (0.89–2.63)	0.123
Suboccipital approach	1.15 (0.65–2.04)	0.636
Dural repair technique		
Pericranium/fascia	0.40 (0.17–0.97)	0.044
Synthetic duraplasty	0.36 (0.14–0.92)	0.033
Fat graft	0.31 (0.11–0.84)	0.022
Combination	0.29 (0.09–0.91)	0.034
Use of bone substitute	0.54 (0.33–0.90)	0.019
Post-op steroid duration		
1–5 days	0.89 (0.29–2.72)	0.843
> 5 days	1.23 (0.67–2.26)	0.513
Post-op CSF diversion		
1–7 days	1.87 (1.13–3.10)	< 0.001
> 7 days	3.38 (1.78–6.41)	< 0.001

Simplifying model through backwards elimination

Model 2 (preliminary)
Age
~~Tobacco use~~
~~Diabetes~~
~~Hx of remote cranial radiation~~
~~Pre-op cranial radiation~~
~~Pre-op steroid use~~
~~Lesion location~~
BMI class
Dural repair technique
~~Post-op steroid duration~~
Use of bone substitute
~~Suboccipital approach~~
Post-op CSF diversion

Remove variable



Did removal of this variable significantly change the ROC curve? (α = 0.05)

No

Yes

Remove from final model

Keep

Model 2 (final)
Age
BMI class
Dural repair technique
Use of bone substitute
Post-op CSF diversion

Table 5. POCC score components

POCC score components	Points assigned
Age	
≥ 55 years	0
< 55 years	+1
BMI class	
Underweight	+1
Healthy	0
Obese	+1
Morbidly obese	+2
Dural repair technique	
Non-primary closure	0
Primary closure	+2
Use of bone substitute	
Yes	0
No	+1
Post-op CSF diversion	
None	0
1–7 days	+1
> 7 days	+3

"Points" derived from coefficients of logistic equation (b_x):

$$\log\left(\frac{y}{1-y}\right) = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \cdots + b_nX_n$$

→ Sum = POCC score

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Table 6. Probability of CSF-related complications for a given POCC score

POCC total score	Probability of CSF-related complication (95% CI)
0	6.2% (3.2 – 9.1%)
1	11.2% (7.5 – 14.9%)
2	19.4% (15.4 – 23.5%)
3	31.6% (26.5 – 36.7%)
4	46.9% (39.0 – 54.8%)
5	62.8% (52.4 – 73.2%)
6	76.4% (65.6 – 87.1%)
7	86.1% (77.0 – 95.1%)
8	92.2% (85.6 – 98.8%)
9	Unknown*

*No patients in our study had a POCC score > 8

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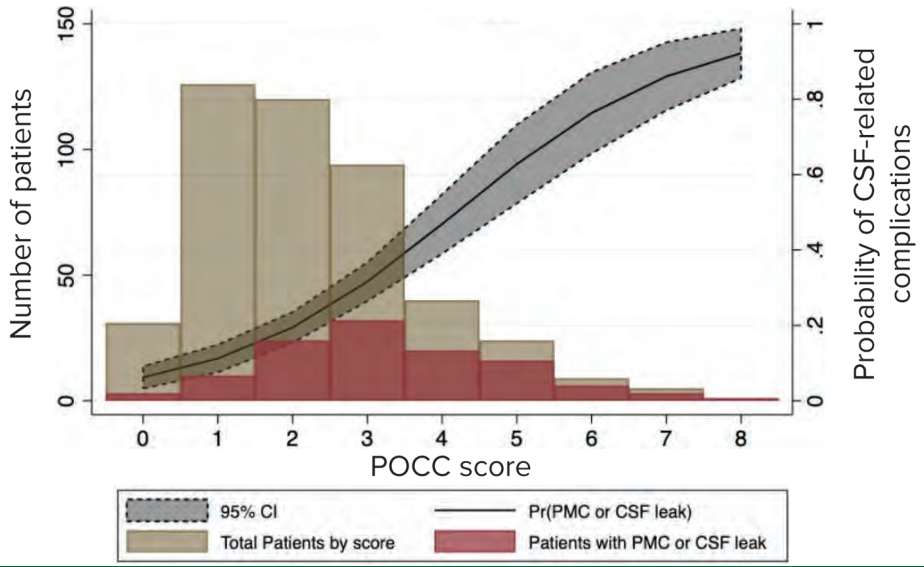
Figure 2. Score distribution and adjusted predictions



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- **Our model correctly predicts whether a patient will develop CSF-related complications in 77% of cases**

- **Sensitivity = 22.6%** → should not be used for screening patients with low risk of CSF leak

- **Specificity = 96.1%** → reliably rules in CSF leak in patients with high POCC score

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Conclusions

- **Protective factors for POCC include:**
  - Age > 55 years
  - Non-primary dural repair
  - Use of bone substitute
- **Risk factors for POCC include:**
  - BMI > 30
  - Use of post-op CSF diversion (correlation, not causation)
- **We created the first POCC predictive scoring system:**
  - Low sensitivity (22.6%)
  - High specificity (96.1%)

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So what?

- To reduce the risk of POCC, consider dural grafts rather than primary closure alone

- Be aware of risk/protective factors for POCC following skull base procedures (age, BMI, post-op CSF diversion)

- Have suspicion for CSF leak in patients with a high POCC score (specificity = 96%)
  - Adjust follow-up timing accordingly

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Limitations

1. Single-institution → External validity?
2. Limited number of POCC (n=115)
3. Multiple surgical indications
4. Multiple surgeons → Internal validity?

Future directions

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CCTS
Center for Clinical and Translational Science

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Questions?

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