Rapid MRI: A Modality for Evaluation of Shunt Malfunction

Presented by:

E. Jacob White MD,

Jared Amos MD

Mentor: Marvin Culbertson,MD

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Original principal investigator:
Ana Varela Windemuller, MD

(Patient guide to Ventriculoperitoneal (VP) shunt surgery 2014)

Background

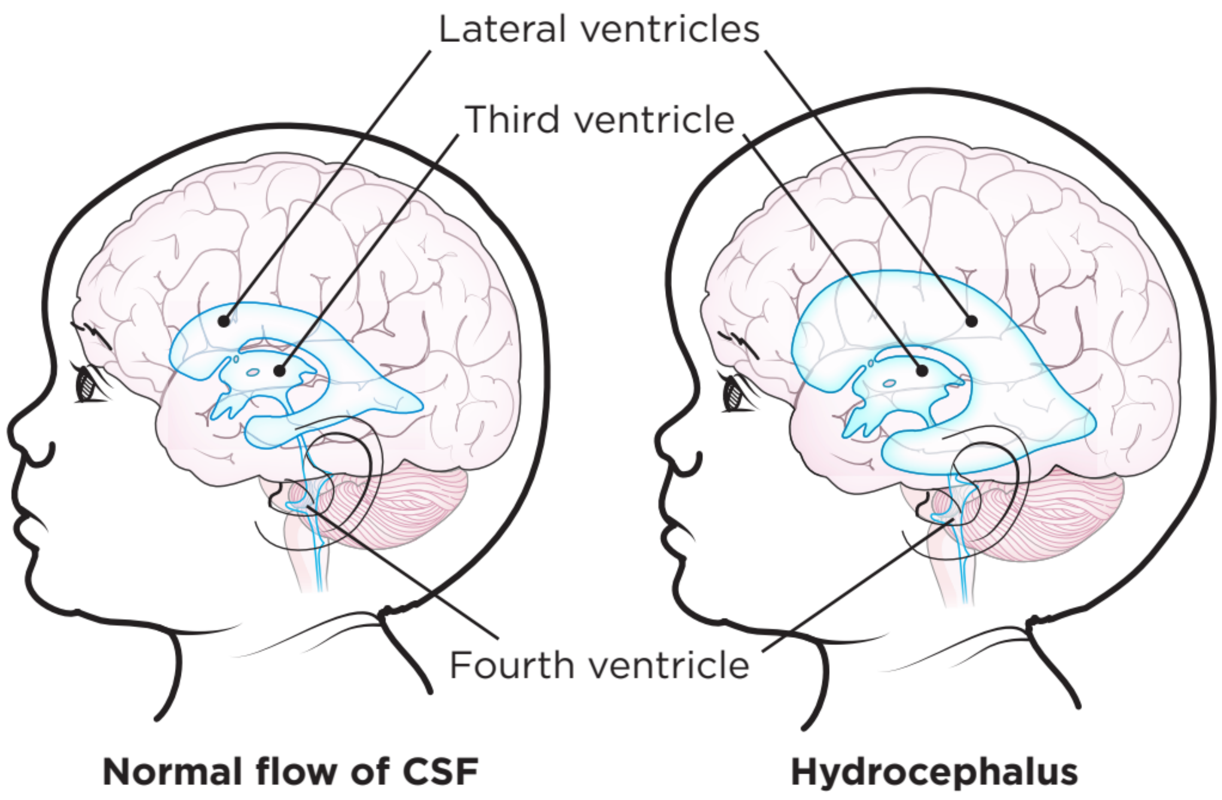


Figure 1: Brain with and without hydrocephalus

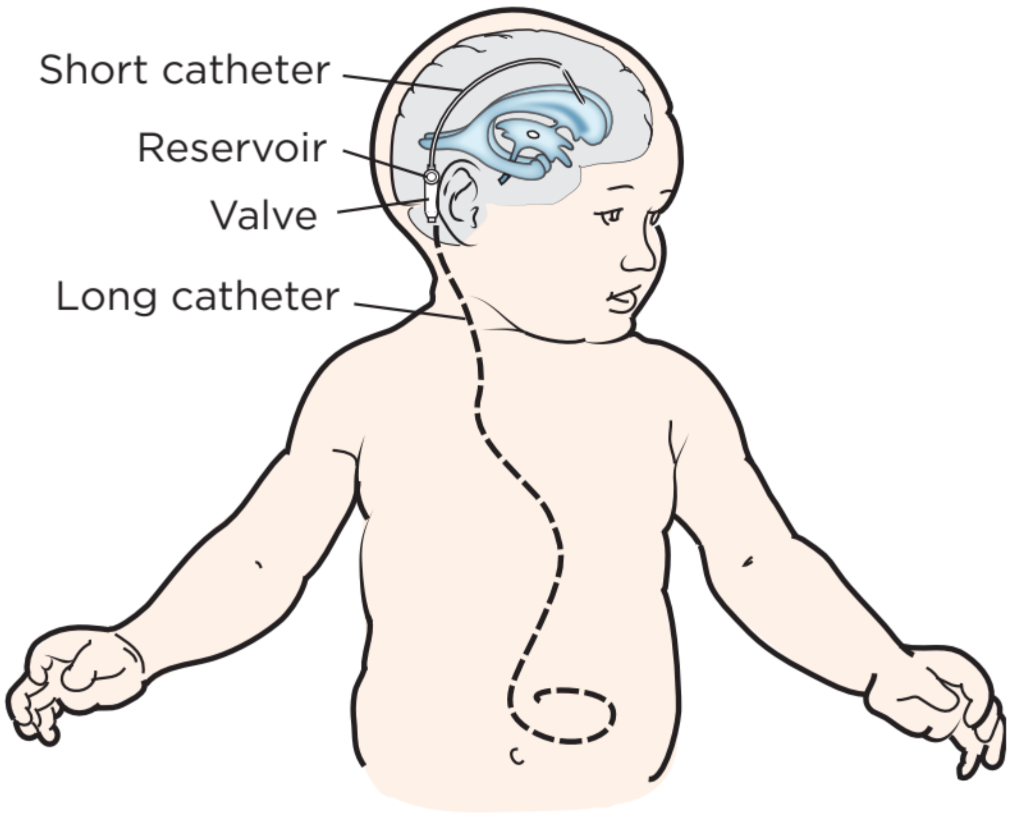
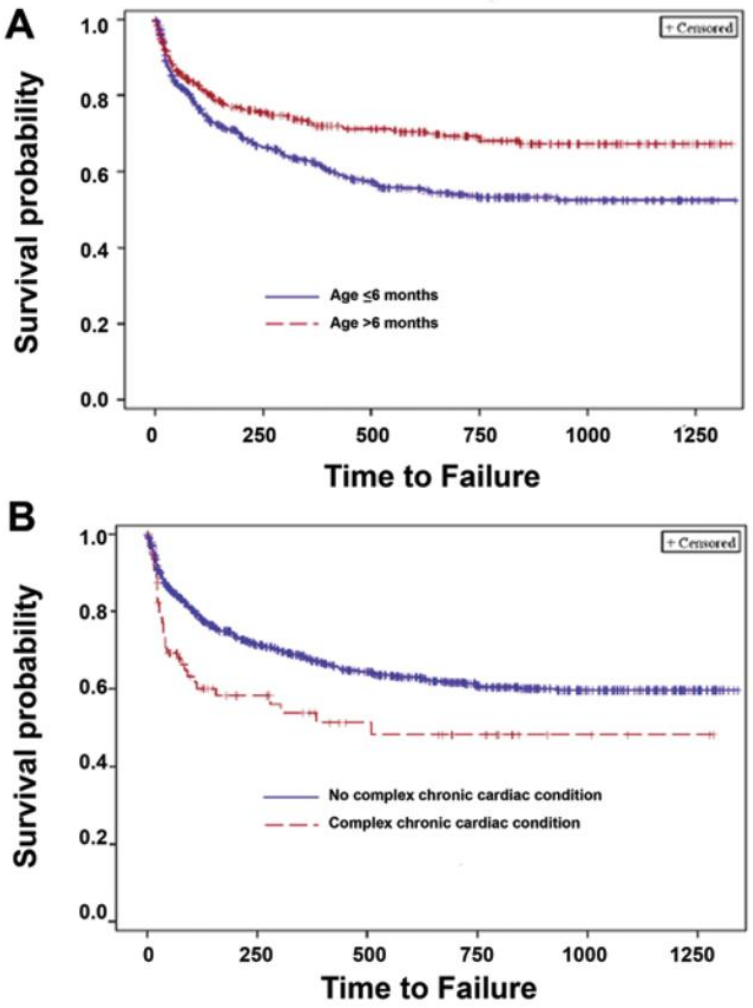


Figure 2: VP shunt

(Riva-Cambrin et al., 2016)

Many Children with VP shunts will have malfunction or infection



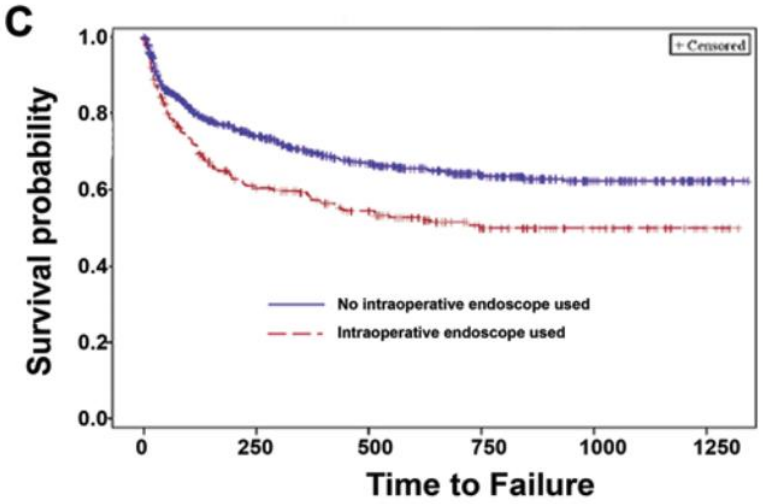


FIG. 1. Survival curves (time to first shunt failure) for 3 risk factors shown to be significant on multivariate analysis: age < 6 months **(A)**, cardiac CCC **(B)**, and use of the intraoperative endoscope **(C)**. Figure is available in color online only.

- 1036 children <19 years old over ~3.5 years
- 36% failure rate
  - Infection (~¼) at 3-432 days
    - mean 45 days
  - Malfunction (~¾) 1-932 days
    - mean 344 days

Children with shunt problems need evaluation

(Hari-Raj et al., 2021)

- estimated ~187,000 ED shunt visits nationally
- high use of CT

(Razmara & Jackson, 2019)

- Peritonitis, papilledema, oculomotor palsy
- headache, nausea, vomiting, altered mental status, seizures, fever

TABLE 2. Diagnostic evaluation and surgeries, pediatric shunt-related ED visits, 2017

Variable	No. (95% CI)	% (95% CI)
Total	16,376 (12,220–20,532)	100
Diagnostic evaluation		
Head CT	7,159 (4,893–9,426)	43.7 (35.6–51.8)
Brain MRI	2,386 (1,280–3,493)	14.6 (8.5–20.6)
Shunt series radiograph	388 (117–660)	2.4 (0.7–4.0)
Shuntogram	2,115 (502–3,728)	12.9 (4.8–21.1)
Shunt tap	190 (54–327)	1.2 (0.3–2.0)
No imaging	6,097 (4,284–7,911)	37.2 (31.2–43.2)
Surgery		
No surgical intervention	10,955 (8,054–13,856)	66.9 (61.9–71.9)
Surgical intervention	5,421 (3,817–7,024)	33.1 (28.1–38.1)

(Pearce et al., 2012)

Shunt evaluation could have consequences

	Male patients		Female patients	
	Brain dose (mGy)	Red bone marrow dose (mGy)	Brain dose (mGy)	Red bone marrow dose (mGy)
Age at brain CT				
0 years	28	8	28	8
5 years	28	9	28	9
10 years	35	6	35	6
15 years	43	4	44	6
20 years	35	2	42	2
Age at chest CT				
0 years	0·4	4	0·4	4
5 years	0·3	3	0·3	3
10 years	0·3	3	0·3	3
15 years	0·2	4	0·3	4
20 years	0·2	4	0·3	4
Age at abdominal CT				
0 years	0·2	3	0·2	3
5 years	0·1	2	0·1	2
10 years	0·1	3	0·1	3
15 years	0·0	3	0·0	3
20 years	0·0	3	0·0	4
Age at extremity CT				
0 years	0·0	1	0·0	1
5 years	0·0	0·2	0·0	0·2
10 years	0·0	0·1	0·0	0·1
15 years	0·0	0·0	0·0	0·0
20 years	0·0	0·0	0·0	0·0

Table 1: **Estimated radiation doses to the brain and red bone marrow from one CT scan, by scan type, sex, and age at scan, as used in this study for scans after 2001**

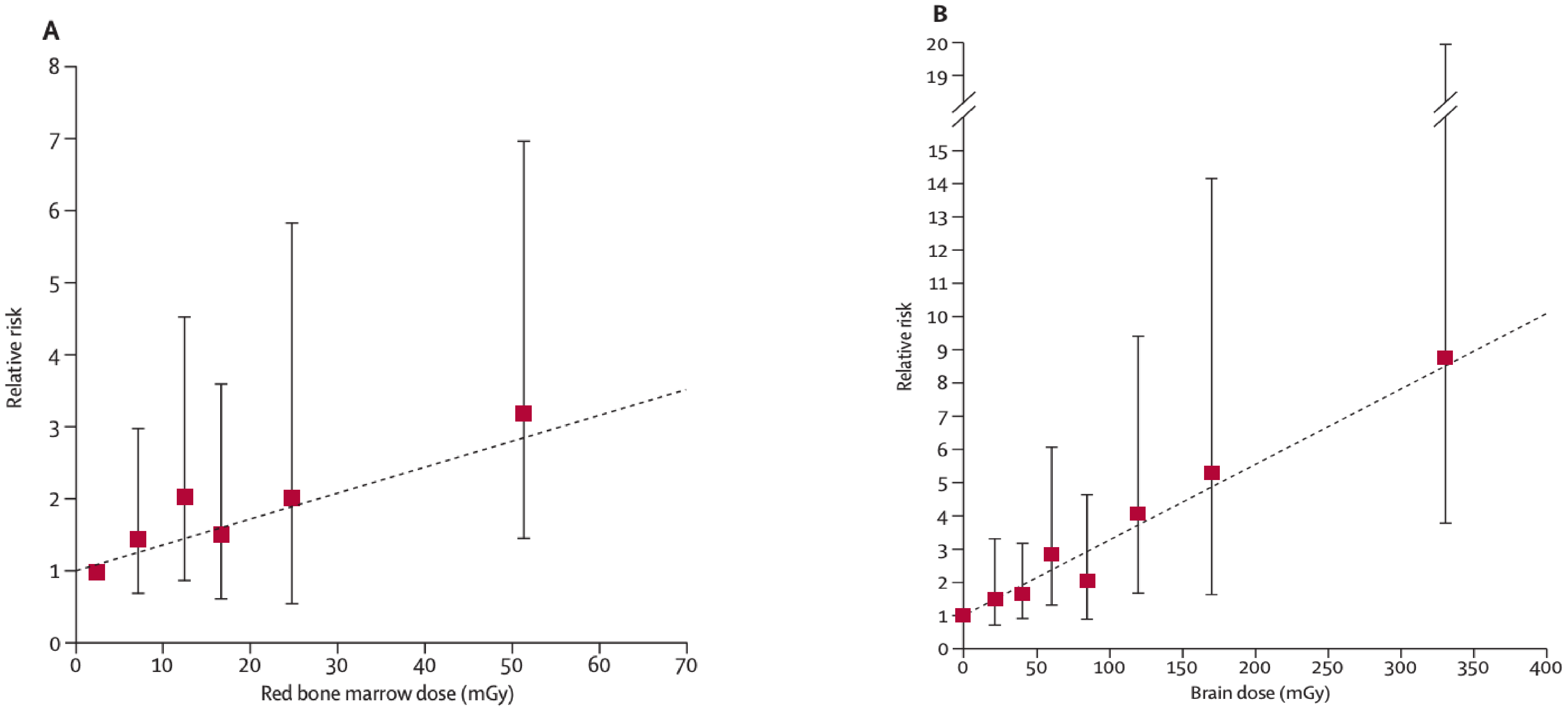
	Leukaemia*		Brain tumours†	
	Cases	Person-years	Cases	Person-years
Sex				
Male	42	953 634	65	657 169
Female	31	764 937	70	529 372
Unknown	1	2413	0	1666
Age at first exposure, years				
0	10	198 052	17	139 414
1–<5	17	262 437	18	185 942
5–<10	17	269 369	27	189 415
10–<15	10	345 320	30	236 891
≥15	20	645 807	43	436 545
Attained age, years				
0–<20	47	900 383	65	537 567
20–<30	23	689 274	53	519 313
30–<35	2	106 376	12	106 376
≥35	2	24 951	5	24 951
Years since first exposure				
0–<10	53	1 266 110	77	733 337
10–<15	15	347 786	45	347 786
15–<20	6	101 213	13	101 213
≥20	0	5871	0	5871
Number of CT scans				
1	45	1 239 170	72	862 661
2–4	22	429 324	50	291 192
≥5	7	52 493	13	34 354
Overall	74	1 720 984	135	1 188 207

Person-year data in the leukaemia group do not sum to the overall number because of rounding. *Follow-up starting 2 years after first CT scan. †Follow-up starting 5 years after first CT scan.

Table 2: **Cases of leukaemia and brain tumours and person-years for patients in the assessed cohort**

(Pearce et al., 2012)

Shunt evaluation could have consequences



Relative radiation

Exam type	Radiation dose
2 view chest xray	10 millirad = 0.1 milligray
2 view abdominal xray	75 millirad = 0.75 milligray
Fluoroscopy	125 millirad /min = 1.25 milligray/min
Computed tomography (head)	2000-4000 millirad = 20-40 milligray
Magnetic resonance imaging	0 millirad = 0 millgray

(special cases)

Ataxia-telangiectasia	Basal cell nevoid syndrome (Gorlin-Goltz syndrome)
Bloom syndrome	Cockayne syndrome
Down syndrome	Fanconi anemia
Gardner syndrome	Nijmegen breakage syndrome
Hereditary retinoblastoma	Usher syndrome

Current situation

1. Many children with ventriculoperitoneal shunts have required CT brain scans to evaluate for acute shunt failure.

1. This evaluation technique increases the risk of developing brain cancer.

1. We should try to reduce use of this modality if clinically safe to do so.

1. Rapid MRI has been shown to have **non inferiority** in diagnosing shunt malfunction compared to CT (Boyle et al., 2014)

Our initial AIM statement

Goal: Reduction in use of CT scan for evaluation of pediatric shunt malfunction from 84% (baseline) to 60% within 6 months of implementing a “rapid MRI” shunt evaluation protocol

Causes Leading to the problem

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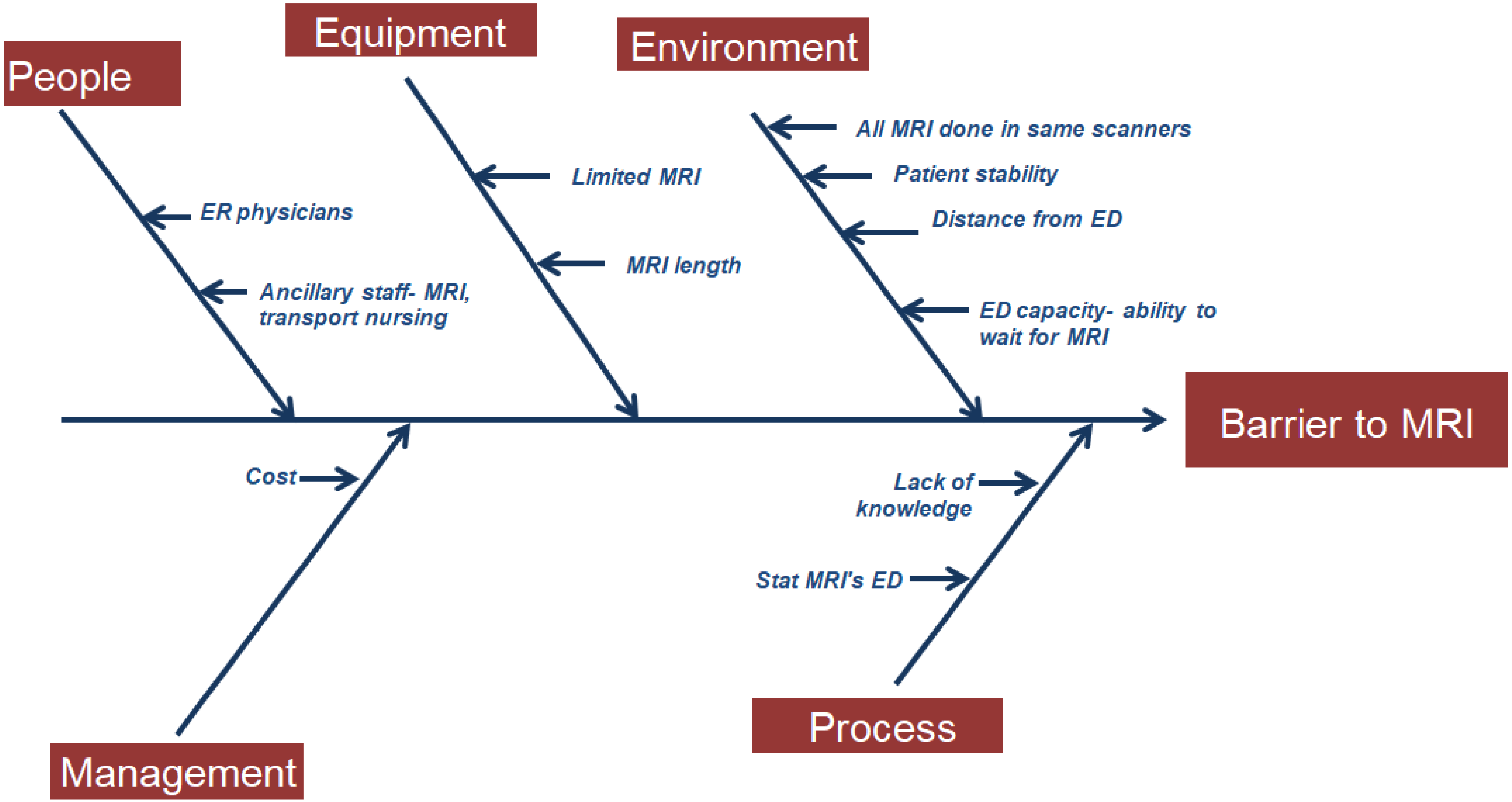


Measures

- Outcome measure: percentage of shunt imaging evaluations per month using CT vs MRI
- Process measures: review of ICD coding, analysis of factors leading to CT scan, ongoing discussion with stakeholders

Act

- Continue to use rapid MRI when appropriate
- Use universal coding to help tracking accuracy
- future iterations to evaluate for risk factors leading to CT use
- Use outside of children's ER

Plan

- get rapid MRI instead of CT
- educate on rapid MRI workflow
- Iteratively review charts to measure % CT

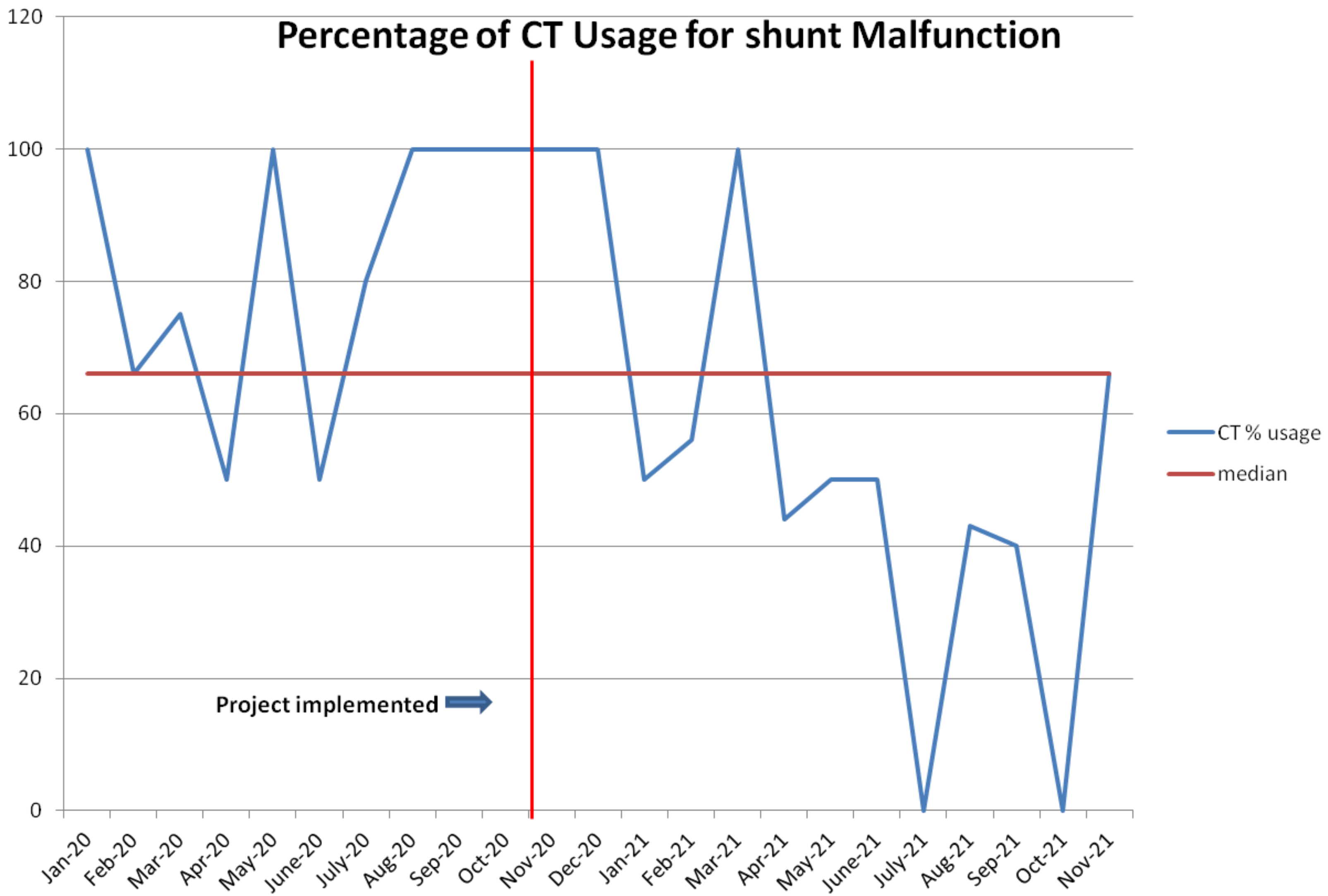
Study

- Coding inconsistency
- Revised mesh term searches
- CT utilization decreased!
- MRI availability can be awkward

Do

- Performed retrospective chart evaluation
- on patients presenting to children's ER
- from 1/2020-11/2021

Results



Percentage of CT Usage for shunt Malfunction
120
100
80
60
40
20
0
Project implemented
Jan-20
Feb-20
Mar-20
Apr-20
May-20
June-20
July-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21
Mar-21
Apr-21
May-21
June-21
July-21
Aug-21
Sep-21
Oct-21
Nov-21
CT % usage
median

Results

	MRI	CT	% CT
before nov 2020	5	26	84%
after nov 2020	19	23	55%
		Absolute reduction	**29%**

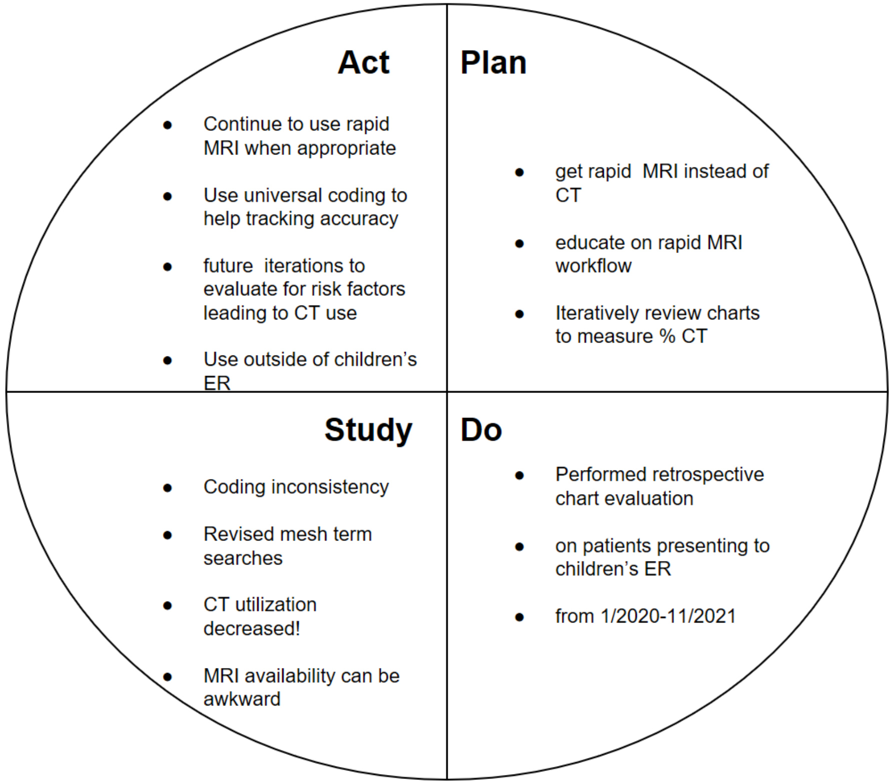
Discussion

AIM statement was accomplished!

CT scan utilization for shunt malfunction was reduced!

Data collection may not be perfectly accurate…

Opportunity for further improvement exists!



Barriers/Lessons Learned

Lack of access to MRI scanner

Unstable patients often receive CT

Provider variation in following protocol

Variation in ICD-10 coding:

(Z98.2, Z 92.89) disorder of cerebral ventricular shunt (T85.9XXS) reprogramming shunt (Z45.41) Shunt obstruction (T85.09XA, T85.09XS, T85.09XD) CSF leak (T85.03XA, T85.03XS, T85.03XD) CSF shunt complication (T85.9XXA, T85.9XXS, T85.9XXD) shunt displacement (T85.02XA, T85.02XS, , T85.02XD) Shunt infection (T85.730A, T85.730S, T85.730D) shunt malfunction T85.01XA, T85.01XS, T85.01XD) presence of programmable shunt (Z96.89, intracranial hypotension following ventricular shunting (G97.2) and left ventricular to right atrial shunt (Q20.5).

Continued improvement

1. Standardization of coding among children’s ER providers to facilitate data tracking

1. Streamlining systems communication to work in emergency rapid MRI where available

1. Additional pediatric MRI?

1. Can we EPIC flag any “frequent fliers”?

Special recognition

Thanks to John Michael Geeslin our EPIC analyst who helped access and compile data reports

Thanks to Dr. Windemuller for starting this QI initiative

Thanks to all departments and staff involved in making rapid MRI’s happen!

References

1. Memorial Sloan Kettering Cancer Center. (2014). Patient guide to Ventriculoperitoneal (VP) shunt surgery. New York, New York. Retrieved May 11, 2022, from https://www.mskcc.org/sites/default/files/node/33641/document/021-peds-vp-2014-6.pdf.
2. Riva-Cambrin, J., Kestle, J. R. W., Holubkov, R., Butler, J., Kulkarni, A. V., Drake, J., Whitehead, W. E., Wellons, J. C., III, Shannon, C. N., Tamber, M. S., Limbrick, D. D., Jr., Rozzelle, C., Browd, S. R., Simon, T. D., & The Hydrocephalus Clinical Research Network. (2016). Risk factors for shunt malfunction in pediatric hydrocephalus: a multicenter prospective cohort study, Journal of Neurosurgery: Pediatrics PED, 17(4), 382-390. Retrieved May 11, 2022, from https://thejns.org/pediatrics/view/journals/j-neurosurg-pediatr/17/4/article-p382.xml
3. Hari-Raj, A., Malthaner, L. Q., Shi, J., Leonard, J. R., & Leonard, J. C. (2021). United States Emergency Department visits for children with cerebrospinal fluid shunts. *Journal of Neurosurgery: Pediatrics*, *27*(1), 23–29. https://doi.org/10.3171/2020.6.peds19729
4. Razmara, A., & Jackson, E. M. (2019). Clinical indicators of pediatric shunt malfunction. *Pediatric Emergency Care*, *37*(11). https://doi.org/10.1097/pec.0000000000001862
5. Pearce MS, Salotti JA, Little MP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. Lancet. 2012;380(9840):499-505. doi:10.1016/S0140-6736(12)60815-0Boyle, T. P., Paldino, M. J., Kimia, A. A., Fitz, B. M., Madsen, J. R., Monuteaux, M. C., & Nigrovic, L. E. (2014). Comparison of rapid cranial MRI to CT for ventricular shunt malfunction. *Pediatrics*, *134*(1). https://doi.org/10.1542/peds.2013-3739
6. Boyle, T. P., Paldino, M. J., Kimia, A. A., Fitz, B. M., Madsen, J. R., Monuteaux, M. C., & Nigrovic, L. E. (2014). Comparison of rapid cranial MRI to CT for ventricular shunt malfunction. *Pediatrics*, *134*(1). https://doi.org/10.1542/peds.2013-3739