



Get Clarity On Generics

Cost-Effective CT & MRI Contrast Agents



**FRESENIUS
KABI**

WATCH VIDEO

AJNR

Utility of Pre-Hematopoietic Cell Transplantation Sinus CT Screening in Children and Adolescents

J.H. Harreld, R.A. Kaufman, G. Kang, G. Maron, W.
Mitchell, J.W. Thompson and A. Srinivasan

This information is current as
of August 4, 2025.

AJNR Am J Neuroradiol published online 9 April 2020
<http://www.ajnr.org/content/early/2020/04/09/ajnr.A6509>

Utility of Pre-Hematopoietic Cell Transplantation Sinus CT Screening in Children and Adolescents

J.H. Harreld, R.A. Kaufman, G. Kang, G. Maron, W. Mitchell, J.W. Thompson, and A. Srinivasan



ABSTRACT

BACKGROUND AND PURPOSE: The clinical benefit of pre-hematopoietic cell transplantation sinus CT screening remains uncertain, while the risks of CT radiation and anesthesia are increasingly evident. We sought to re-assess the impact of screening sinus CT on pretransplantation patient management and prediction of posttransplantation invasive fungal rhinosinusitis.

MATERIALS AND METHODS: Pretransplantation noncontrast screening sinus CTs for 100 consecutive patients (mean age, 11.9 ± 5.5 years) were graded for mucosal thickening (Lund-Mackay score) and for signs of noninvasive or invasive fungal rhinosinusitis (sinus calcification, hyperattenuation, bone destruction, extrasinus inflammation, and nasal mucosal ulceration). Posttransplantation sinus CTs performed for sinus-related symptoms were similarly graded. Associations of Lund-Mackay scores, clinical assessments, changes in pretransplantation clinical management (additional antibiotic or fungal therapy, sinonasal surgery, delayed transplantation), and subsequent development of sinus-related symptoms or invasive fungal rhinosinusitis were tested (exact Wilcoxon rank sums, Fisher exact test, significance $P < .05$).

RESULTS: Mean pretransplantation screening Lund-Mackay scores ($n = 100$) were greater in patients with clinical symptoms (8.07 ± 6.00 versus 2.48 ± 3.51 , $P < .001$) but were not associated with pretransplantation management changes and did not predict posttransplantation sinus symptoms ($n = 21$, $P = .47$) or invasive fungal rhinosinusitis symptoms ($n = 2$, $P = .59$).

CONCLUSIONS: Pre-hematopoietic cell transplantation sinus CT does not meaningfully contribute to pretransplantation patient management or prediction of posttransplantation sinus disease, including invasive fungal rhinosinusitis, in children. The risks associated with CT radiation and possible anesthesia are not warranted in this setting.

ABBREVIATIONS: ENT = ear, nose, and throat; GVHD = graft versus host disease; HCT = hematopoietic cell transplantation; IFRS = invasive fungal rhinosinusitis

Due to prolonged immunosuppression, children undergoing hematopoietic cell transplantation (HCT) are at increased risk of opportunistic infections, including potentially lethal invasive fungal rhinosinusitis (IFRS).¹⁻⁵ Children at St. Jude Children's Research Hospital, therefore, undergo rigorous pretransplantation evaluation, including ear, nose, and throat

(ENT) examination, infectious disease risk assessment, fungal serologies, and noncontrast sinus CT.

However, the clinical utility of screening sinus CT remains unclear, and the practice is not universal. According to the American Academy of Pediatrics and the American College of Radiology, uncomplicated sinusitis should be a clinical diagnosis,^{6,7} and several large studies ($n \geq 100$) have failed to identify pre-HCT imaging features predictive of post-HCT sinusitis.⁸⁻¹⁰ Fewer studies have evaluated the contribution of pretransplantation CT to patient management or prediction of posttransplantation IFRS. A small study in adults found that screening sinus CT did not contribute to a pretransplantation diagnosis or management or predict posttransplantation sinusitis or IFRS, but it was limited by a small sample size.¹¹ A study of 187 children reported an association between pre-HCT sinus CT findings and management changes, but while 119 (64%) had abnormal sinus CT findings, only 29 had symptoms and were treated, suggesting symptoms, not imaging, drove treatment.¹²

Received June 3, 2019; accepted after revision March 3, 2020.

From the Departments of Diagnostic Imaging (J.H.H., R.A.K.), Biostatistics (G.K.), Infectious Diseases (G.M.), Bone Marrow Transplantation and Cellular Therapy (W.M., A.S.), and Surgery (J.W.T.), St. Jude Children's Research Hospital, Memphis, Tennessee; and Department of Otolaryngology (J.W.T.), University of Tennessee Health Sciences Center, Memphis, Tennessee.

This work was supported, in part, by grant No. CA21765 from the National Cancer Institute and by the American Lebanese and Syrian Associated Charities.

Please address correspondence to Julie H. Harreld, MD, Department of Diagnostic Imaging, St. Jude Children's Research Hospital, 262 Danny Thomas Place, MS 220, Memphis, TN 38105; e-mail: Julie.harreld@stjude.org

Indicates open access to non-subscribers at www.ajnr.org

<http://dx.doi.org/10.3174/ajnr.A6509>

While the benefits of pre-HCT sinus CT remain unclear, the risks associated with sinus CT are well-established and include a low-but-real risk of radiation-induced cancers^{13,14} and early cataract formation.¹⁵ Evidence is also emerging that anesthesia, required by some children to complete CT, may negatively impact cognitive development.^{16,17} On the other hand, advances in fungal prophylaxis have significantly reduced the incidence of invasive fungal infections in immunocompromised children.¹⁸

Given these potential shifts in the risk-benefit ratio, we sought to re-evaluate the clinical utility of pre-HCT screening sinus CT for IFRS risk assessment and its role in pre-HCT management of pediatric patients.

MATERIALS AND METHODS

With institutional review board approval and waiver of consent, imaging, clinical, ENT risk assessment, and laboratory data were prospectively recorded for 100 sequential participants who had pre-HCT screening sinus CT at our institution between June 2015 and April 2017. A sample size of 100 was chosen to detect at least 1 case of IFRS, which has an incidence of approximately 2% in patients with hematologic disorders.² The patients' medical records were reviewed for microbiologic diagnosis of IFRS for at least 100 days posttransplantation. With additional institutional review board approval and waiver of consent, medical records were retrospectively reviewed for subsequent clinical, imaging, and laboratory data until the patient's death or November 2017.

Clinic and Laboratory

Recorded data included primary diagnosis; transplant donor type; absolute neutrophil count at imaging; pretransplantation imaging indication; development of posttransplantation graft versus host disease (GVHD) grades II–IV (moderate-to-life-threatening); pretransplantation galactomannan (*Aspergillus* antigen); sinonasal symptoms (rhinorrhea, congestion, nasal/facial pain, swelling, visible nasal lesion), or fever at pretransplantation evaluation; and changes to pretransplantation management (changes in fungal prophylaxis regimen, addition of antibiotics, sinonasal operation, or delay of HCT) attributable to screening sinus CT.

ENT pretransplantation risk assessment included visualization of the nasal septum, palate, and back of throat under magnification and complete allergy and sinusitis histories. These findings were summarized as “at-risk” or “not at-risk” for IFRS.

For patients requiring post-HCT sinus imaging for symptoms, we recorded symptoms, galactomannan serologies, endoscopy findings, fungal organism (if applicable), and consecutive days of neutropenia (absolute neutrophil count < 500/mm³) immediately preceding imaging. The date of acquisition of tissue positive for IFRS by microbiologic/pathologic examination was considered the date of diagnosis.

Imaging

CTs were axially acquired with a section thickness of ≤2.5 mm on a LightSpeed VCT or Revolution CT scanner (GE Healthcare) with bone and soft-tissue reconstructions. The average effective dose for all ages was ~0.8 mSv; the eye/lens dose was 0.7–1.2 mGy.

Images were reviewed in consensus by a board-certified pediatric radiologist with 40 years' experience (R.A.K.) and a board-certified neuroradiologist with 10 years' experience (J.H.H.) for the presence or absence of bone destruction, extrasinus inflammation, and nasal mucosal ulceration, associated with IFRS.^{4,19–22} Because noninvasive fungal disease could theoretically predispose to IFRS with pre-HCT conditioning/immunodepletion, the presence of calcifications and sinus hyperdensity was also noted.²³

Each anterior and posterior ethmoid, maxillary, frontal, and sphenoid sinus was graded as clear = 0, partially opacified = 1, or completely opacified = 2; each ostiomeatal unit was graded as clear = 0 or occluded = 2; and the numbers were added per Lund and Mackay.²⁴ To account for age-related differences in sinus development, we calculated an adjusted Lund-Mackay score as²⁵

Adjusted Lund Score =

$$\text{Raw score} \times \frac{24}{\text{Maximum Lund for No. Pneumatized Sinuses}}.$$

Statistical Analysis

Sinus CT scores, laboratory values, symptoms, changes in management, and ENT risk were compared using the Fisher exact test or the Pearson χ^2 test for categorical variables and a 2-sample *t* test or (exact) Wilcoxon rank sum test for continuous variables, based on the normality assumption. The Lund-Mackay scores between pre- and posttransplantation were compared using a 1-sample *t* test or Wilcoxon signed rank test, depending the normality assumption. All *P* values are 2-sided and were considered statistically significant if <.05. Statistical analyses were performed with R-3.6.1 (R statistical and computing software; <http://www.r-project.org/>).

RESULTS

One hundred participants (60 males, 40 females; 8 months to 24 years of age; mean, 11.9 ± 5.5 years; males, 11.6 ± 5.7 years; females, 12.5 ± 5.2 years) had screening sinus CT an average of 24.6 ± 9.6 days before transplantation for IFRS risk assessment. Patient characteristics, imaging, and clinical findings are summarized in Table 1.

Follow-up for survivors (*n* = 82) ranged from 189 to 889 days post-HCT. During the follow-up period, 9 patients died of relapsed disease from 28 to 519 days post-HCT. Nine died of complications between 23 and 557 days post-HCT, none related to sinus disease.

Clinical Symptoms and Provided Imaging Indications

At the time of the screening sinus CT, 18 patients had sinonasal symptoms documented in the medical record: Thirteen had rhinorrhea, 2 had nasal congestion, and 3 had both. No patients had overt signs or symptoms of IFRS or complicated rhinosinusitis—localized facial pain or inflammation, nasal ulcer/eschar, fever, or altered mental status—documented in the medical record at the time of CT.

The provided indication for 98/100 screening sinus CTs was “pretransplantation evaluation.” Symptoms mentioned for 2 patients did not match the medical record, possibly being erroneous or outdated. One request indicated fever without localizing symptoms, though the clinical examination documented congestion and rhinorrhea without fever. The other request indicated possible periorbital edema, which was not present on CT or the physical examination. On examination, the patient had clear rhinorrhea and nasal wash positive for enterovirus/rhinovirus and was determined eligible for transplantation the same day.

Pretransplantation Screening and Management

Mucosal thickening was present (Lund-Mackay score of ≥ 1) at screening in 66/100 patients, including 48/82 (58.5%) asymptomatic patients and all 18 symptomatic patients. No asymptomatic patients received antibiotics based on sinus CT.

The Lund-Mackay score was higher for patients with symptoms documented in the medical record ($P < .0001$, Table 2). Patients with clinical symptoms were more likely to be treated

with antibiotics (5/18 with symptoms versus 0/82 asymptomatic, $P = .0001$). The Lund-Mackay scores were greater for symptomatic patients who received antibiotics ($n = 5$, 12.8 ± 5.72) compared with those who did not ($n = 13$, 6.25 ± 5.25), but this finding did not reach statistical significance ($P = .058$) (Table 2).

All 5 patients treated with pretransplantation antibiotics had clinical sinusitis. Nasal wash was positive for enterovirus/rhinovirus in 3/5 (60%). Two received antibiotics primarily for pneumonia and secondary coverage of possible bacterial sinusitis. None developed IFRS before or after transplantation.

One patient had a smooth nasal septal perforation, which was negative for IFRS at screening endoscopy. Two others had sinus calcifications. All 3 were asymptomatic, and none developed IFRS or symptoms posttransplantation. No patients (0/100) had sinus hyperdensity, nasal ulceration, extrasinus inflammation, or bone destruction at screening.

No patients underwent a pretransplantation sinus operation, received new antifungal therapy, or had HCT delayed as a result of screening sinus CT.

Table 1: Patient characteristics

Characteristics	
No.	100
Male	60
Female	40
Age (mean) (yr)	11.9 ± 5.5
Primary diagnosis (No.) (%)	
Hematologic malignancy	65, 65%
Acute myeloid leukemia	34, 34%
Acute lymphoblastic leukemia	17, 17%
Hodgkin lymphoma	8, 8%
Myelodysplastic syndrome	5, 5%
Anaplastic large-cell lymphoma	1, 1%
Hematologic disorder	5, 5%
Severe aplastic anemia	3, 3%
Sickle cell disease	2, 2%
Solid tumor	28, 28%
Neuroblastoma	15, 15%
Ewing sarcoma	9, 9%
Germ cell tumor	3, 3%
Desmoplastic small round cell tumor	1, 1%
Immune disorder	2, 2%
Severe combined immunodeficiency	1, 1%
Wiskott-Aldrich syndrome	1, 1%
Transplant donor (No.) (%)	
Allogenic	66, 66%
Autologous	34, 34%
Disease status at transplantation (No.) (%)	
Complete remission	82, 82%
Active disease	18, 18%
T-cell depletion (No.) (%)	2, 2%
GVHD II–IV (No.) (%)	15, 15%

Table 2: Pretransplantation sinus CT Lund-Mackay scores, sinonasal symptoms, and management

	No. (Frequency)	Pre-HCT Lund-Mackay Score (Mean)	P Value
All at screening	100 (100%)	3.48 ± 4.58	
No symptoms at screening	82 (82%)	2.48 ± 3.51	$< .001$
Symptoms at screening	18 (18%)	8.07 ± 6.00	
With symptoms, received antibiotics	5 (28%)	12.80 ± 5.72	.058
With symptoms, no antibiotics	13 (72%)	6.25 ± 5.25	

Posttransplantation Imaging

Symptoms prompted posttransplantation evaluation of 21 patients whose Lund-Mackay scores had increased (7.43 ± 6.36) from baseline screening CT (3.87 ± 4.99 ; $P = .007$).

Two of the 21 (9.5%) symptomatic patients or 2% (2/100) of the entire cohort developed IFRS, 615 days (*Bipolaris* spp) and 248 days (*Fusarium* spp) posttransplantation. Pretransplantation, neither had symptoms. These 2 patients had lower Lund-Mackay scores (4.5 ± 3.54) than symptomatic patients without IFRS ($n = 19$, 7.74 ± 6.57), but this finding was not statistically significant ($P = .59$).

Prediction of Posttransplantation Sinus Disease

The degree of mucosal thickening (Lund-Mackay score) on pretransplantation CT did not predict posttransplantation symptoms ($P = .47$) or posttransplantation IFRS ($P = .58$) (Table 3).

The pretransplantation test for galactomannan was negative in all patients at screening. The mean absolute neutrophil count at screening was 2510 ± 5568 (range, 0–50,200). There was no association between screening absolute neutrophil count and pre-HCT symptoms, post-HCT symptoms, or post-HCT IFRS. Disease status, transplant donor, T-cell depletion, and posttransplantation GVHD grades II–IV did not predict development of IFRS ($P = 1$ for all; Table 4).

Of 96 participants evaluated by ENT, 29 were considered at risk for IFRS. ENT risk assessment did not predict development of IFRS ($P = .61$). There was no association between the Lund-Mackay score and the ENT risk stratum ($P = .99$).

The presence of symptoms before transplantation ($n = 18$) did not predict posttransplantation symptoms ($n = 21$); only 3 patients were symptomatic both before and after transplantation ($P = .62$).

DISCUSSION

In this study, we found no association between pre-HCT screening sinus CT and changes in pretransplantation

Table 3: Pre-HCT Lund-Mackay scores versus posttransplantation sinus outcomes

	No. (Frequency)	Pre-HCT Lund-Mackay Score (Mean)	P Value
All at screening	100 (100%)	3.48 ± 4.58	
No post-HCT symptoms	79 (79%)	3.38 ± 4.49	.47
Post-HCT symptoms	21 (21%)	3.86 ± 5.00	
Post-HCT symptoms, IFRS	2 (9.5%)	4.00 ± 4.24	.58
Post-HCT symptoms, no IFRS	19 (90.5%)	3.84 ± 5.17	

Table 4: Clinical findings at screening for patients who did and did not develop IFRS after transplantation

	All at Pre-HCT Screen	No Post-HCT IFRS	Post-HCT IFRS	P Value
No.	100	98	2	
ENT risk estimate (No.) (frequency)				
At risk	29 (29%)	28 (29%)	1 (50%)	.61
Low risk	67 (67%)	62 (63%)	1 (50%)	
Not evaluated	4 (4%)	8 (8%)	0	
ANC at imaging (mean)	2510 ± 5568	2524 ± 5622	1800 ± 1697	.86
Transplant donor (No.) (frequency)				
Allogenic	66 (66%)	65 (66%)	1 (50%)	1
Autologous	34 (34%)	33 (34%)	1 (50%)	
Disease status at transplantation (No.) (frequency)				
Complete remission	82 (82%)	80 (80%)	2 (100%)	1
Active disease	18 (18%)	18 (18%)		
T-cell depletion (No.) (frequency)	2 (2%)	2 (2%)	0	1
GVHD II–IV (No.) (frequency)	15 (15%)	15 (15%)	0	1

Note:—ANC indicates absolute neutrophil count.

patient management, including the addition of antibiotics or changes to the antifungal prophylaxis regimen or transplantation schedule. Like other authors,^{9,10} we found no association between pretransplantation Lund-Mackay scores and the development of posttransplantation sinus symptoms or IFRS. Unlike Won et al,⁹ we did not find pre-HCT symptoms predictive of post-HCT symptoms. In our study, clinical and laboratory features, including pretransplantation ENT evaluation, also failed to predict posttransplantation sinusitis and IFRS. Our findings are in agreement with adult studies by Thompson et al⁸ ($n = 100$) and Moeller et al¹¹ ($n = 71$), which found no benefit at all for pre-HCT sinus screening. A similar study of 1589 adult patients with kidney transplants found no increase in the prevalence of rhinosinusitis posttransplantation, concluding that routine pretransplantation sinonasal evaluation is not warranted.²⁶

The origins and evidence supporting pre-HCT screening sinus CT are unclear. In a 1995 study, Shibuya et al²⁷ recommended screening CT on the basis of 33/107 pretransplantation patients with clinical sinusitis and imaging abnormalities, despite imaging only symptomatic patients. At our institution, the practice may date back to a 1982 article by Bartley et al,²⁸ prompting routine screening abdominal CT for detection of hepatosplenic fungal abscesses, to which chest and sinus CT were subsequently added. Subsequent work by Kasow et al¹² found no utility in routine chest or abdominal CT in asymptomatic patients but suggested that sinus CT drove changes in management. However, supporting data were sparse, and the number of treated and symptomatic patients precisely matched ($n = 29/187$, 15.5%), suggesting a clinical basis for treatment. In a small ($n = 51$) study

in 2000, Billings et al²⁹ found that children with severe sinus disease on pre-bone marrow transplantation CT were more likely to have sinusitis after bone marrow transplantation and reported a trend toward decreased survival in these children, but these findings were not statistically significant ($P = .750$). In a study of 252 adults, Won et al⁹ found that asymptomatic radiographic sinus abnormalities did not increase the risk of post-HCT sinusitis, but they also reported a trend toward reduction of post-HCT sinusitis with the treatment of asymptomatic abnormalities, which did not reach statistical significance ($P = .057$). To our knowledge, no investigators have identified pretransplantation imaging predictors of IFRS.

It has been suggested that CT might be a surrogate for inflammatory symptoms in immunocompromised patients, who may not be able to mount an inflammatory response.^{27,30}

However, evidence shows that clinical sinusitis and imaging severity go hand in hand, even in immunocompromised children.^{10,29,30} This was also true in our study, in which Lund-Mackay scores were greater in the presence of symptoms. The American Academy of Pediatrics and American College of Radiology guidelines dictate that diagnosis and treatment of acute sinusitis should be clinical, with imaging reserved for suspicion of orbital or CNS complications.^{6,7} IFRS typically presents with a combination of fever, facial pain, nasal congestion, headache, eye symptoms, and/or facial swelling, which should also prompt imaging, and likely endoscopy.^{3-5,31} On pretransplantation physical examination, none of the 100 patients in our series had findings suggestive of orbital, CNS, or fungal involvement warranting imaging evaluation.

On the other hand, isolated radiographic abnormalities, common in asymptomatic children,³² may be confusing or lead to overtreatment.³³ In our series, 58.8% of 82 asymptomatic children had mucosal thickening on pre-HCT CT. As suggested by other authors,^{9,30} a thorough sinus history and examination are likely to be more meaningful than CT, without the associated risk of radiation-induced cancers and cataracts.^{13-15,34}

Our findings suggest that there is insufficient benefit to justify the risks of radiation exposure, and potentially of anesthesia, associated with pre-HCT screening CT.^{13,15-17} To reduce the risk of radiation-induced cancers, to which children are particularly susceptible,³⁴ the As Low As Reasonably Achievable principle dictates the use of the lowest possible radiation dose necessary for diagnosis.³⁴ Most pediatric imaging centers, like ours, use targeted protocols with dose-reduction techniques like iterative reconstruction and low tube voltage wherever possible.³⁵

However, the best way to reduce the pediatric radiation dose is to eliminate imaging that does not meaningfully contribute to diagnosis or management.¹⁴ The preponderance of the evidence, including ours, suggests that pre-HCT screening sinus CT falls into this category and that the practice should be discontinued.

This study had several weaknesses. Clinical evaluation was rarely performed on the same day as screening sinus CT, and symptoms were recorded from the medical record because they were frequently omitted from the imaging requisitions. These features could result in a mismatch between symptoms and imaging manifestations. Although a trend toward greater Lund-Mackay scores in symptomatic patients receiving antibiotics was not statistically significant, the sample size was small. It is possible that the degree of mucosal thickening on sinus CT unduly influenced the decision to treat with antibiotics, which should be based on history and examination.^{6,7} Mucosal thickening on CT does not differentiate between bacterial and viral pathogens, and 3 of 5 patients receiving antibiotics in this study had nasal washes positive for viral pathogens. Next, only patients undergoing imaging work-up were considered symptomatic post-HCT. It is possible that some patients were treated on the basis of clinical symptoms with no imaging, though observation of our current clinical practice suggests that this is unlikely. Similar to other studies,^{2,4} only 2% (2/100) of this study population ultimately developed IFRS, limiting statistical evaluation. However, neither had clinical or imaging findings suspicious for IFRS pretransplantation. Although a single-institution sample size of 100 children undergoing HCT may be considered large, given the rarity of the condition, it was nonetheless insufficient to identify clinical or imaging features associated with IFRS. A retrospective case-control study would be more practical for such analysis.

CONCLUSIONS

Pre-HCT sinus CT does not meaningfully contribute to pretransplantation patient management or prediction of posttransplantation sinus disease, including IFRS, in children. The risks associated with CT radiation and possible anesthesia are not warranted in this setting.

ACKNOWLEDGMENTS

The authors wish to thank Edwina Anderson and Cindy Morris for assistance with data collection.

Disclosures: Julie H. Harrel—RELATED: Grant: National Cancer Institute, Comments: Grant No. CA21765 supports the St. Jude Cancer Center*; Other: American Lebanese and Syrian Associated Charities, Comments: The American Lebanese and Syrian Associated Charities is the fundraising arm of St. Jude.* Gabriela Maron—UNRELATED: Other: Astellas Pharma Inc, Comments: local Principal Investigator for pharmaceutical research protocols.* Jerome W. Thompson—UNRELATED: Employment: University of Tennessee Faculty. *Money paid to the institution.

REFERENCES

- Deo SS, Gottlieb DJ. Adoptive T-cell therapy for fungal infections in haematology patients. *Clin Transl Immunology* 2015;4:e40 [CrossRef Medline](#)
- Chen CY, Sheng WH, Cheng A, et al. Invasive fungal sinusitis in patients with hematological malignancy: 15 years' experience in a single university hospital in Taiwan. *BMC Infect Dis* 2011;11:250 [CrossRef Medline](#)
- Gillespie MB, O'Malley BW, Francis HW. An approach to fulminant invasive fungal rhinosinusitis in the immunocompromised host. *Arch Otolaryngol Head Neck Surg* 1998;124:520–26 [CrossRef Medline](#)
- Park AH, Muntz HR, Smith ME, et al. Pediatric invasive fungal rhinosinusitis in immunocompromised children with cancer. *Otolaryngol Head Neck Surg* 2005;133:411–16 [CrossRef Medline](#)
- Smith A, Thimmappa V, Shepherd B, et al. Invasive fungal sinusitis in the pediatric population: systematic review with quantitative synthesis of the literature. *Int J Pediatr Otorhinolaryngol* 2016;90:231–35 [CrossRef Medline](#)
- Kirsch CF, Bykowski J, Aulino JM, et al; Expert Panel on Neurologic Imaging. ACR Appropriateness Criteria Sinonasal Disease. *J Am Coll Radiology* 2017;14:S550–59 [CrossRef Medline](#)
- Wald ER, Applegate KE, Bordley C, et al; American Academy of Pediatrics. Clinical practice guideline for the diagnosis and management of acute bacterial sinusitis in children aged 1 to 18 years. *Pediatrics* 2013;132:e262–80 [CrossRef Medline](#)
- Thompson AM, Couch M, Zahurak ML, et al. Risk factors for post-stem cell transplant sinusitis. *Bone Marrow Transplant* 2002;29:257–61 [CrossRef Medline](#)
- Won YW, Yi SY, Jang JH, et al. Retrospective analysis of paranasal sinusitis in patients receiving hematopoietic stem cell transplantation. *Int J Hematol* 2011;93:383–88 [CrossRef Medline](#)
- Zamora CA, Oppenheimer AG, Dave H, et al. The role of screening sinus computed tomography in pediatric hematopoietic stem cell transplant patients. *J Comput Assist Tomogr* 2015;39:228–31 [CrossRef Medline](#)
- Moeller CW, Martin J, Welch KC. Sinonasal evaluation preceding hematopoietic transplantation. *Otolaryngol Head Neck Surg* 2011;144:796–801 [CrossRef Medline](#)
- Kasow KA, Krueger J, Srivastava DK, et al. Clinical utility of computed tomography screening of chest, abdomen, and sinuses before hematopoietic stem cell transplantation: the St. Jude experience. *Biol Blood Marrow Transplant* 2009;15:490–95 [CrossRef Medline](#)
- Miglioretti DL, Johnson E, Williams A, et al. The use of computed tomography in pediatrics and the associated radiation exposure and estimated cancer risk. *JAMA Pediatr* 2013;167:700–07 [CrossRef Medline](#)
- Donnelly LF. Reducing radiation dose associated with pediatric CT by decreasing unnecessary examinations. *AJR Am J Roentgenol* 2005;184:655–57 [CrossRef Medline](#)
- Fish DE, Kim A, Ornelas C, et al. The risk of radiation exposure to the eyes of the interventional pain physician. *Radiology Res Pract* 2011;2011:609537 [CrossRef Medline](#)
- Banerjee P, Rossi MG, Angheliescu DL, et al. Association between anesthesia exposure and neurocognitive and neuroimaging outcomes in long-term survivors of childhood acute lymphoblastic leukemia. *JAMA Oncol* 2019 Jun 20. [Epub ahead of print] [CrossRef Medline](#)
- Lei S, Ko R, Sun LS. Neurocognitive impact of anesthesia in children. *Adv Anesth* 2018;36:125–37 [CrossRef Medline](#)
- Maron GM, Hayden RT, Rodriguez A, et al. Voriconazole prophylaxis in children with cancer: changing outcomes and epidemiology of fungal infections. *Pediatr Infect Dis J* 2013;32:e451–55 [CrossRef Medline](#)
- DelGaudio JM, Swain RE Jr, Kingdom TT, et al. Computed tomographic findings in patients with invasive fungal sinusitis. *Arch Otolaryngol Head Neck Surg* 2003;129:236–40 [CrossRef Medline](#)
- Groppa ER, El-Sayed IH, Aiken AH, et al. Computed tomography and magnetic resonance imaging characteristics of acute invasive fungal sinusitis. *Arch Otolaryngol Head Neck Surg* 2011;137:1005–10 [CrossRef Medline](#)
- Ni Mhurchu E, Ospina J, Janjua AS, et al. Fungal rhinosinusitis: a radiological review with intraoperative correlation. *Can Assoc Radiology J* 2017;68:178–86 [CrossRef Medline](#)

22. Middlebrooks EH, Frost CJ, De Jesus RO, et al. **Acute invasive fungal rhinosinusitis: a comprehensive update of CT findings and design of an effective diagnostic imaging model.** *AJNR Am J Neuroradiol* 2015;36:1529–35 [CrossRef Medline](#)
23. Aribandi M, McCoy VA, Bazan C 3rd. **Imaging features of invasive and noninvasive fungal sinusitis: a review.** *Radiographics* 2007;27:1283–96 [CrossRef Medline](#)
24. Lund VJ, Kennedy DW. **Staging for rhinosinusitis.** *Otolaryngol Head Neck Surg* 1997;117:S35–40 [CrossRef](#)
25. Hill M, Bhattacharyya N, Hall TR, et al. **Incidental paranasal sinus imaging abnormalities and the normal Lund score in children.** *Otolaryngol Head Neck Surg* 2004;130:171–75 [CrossRef Medline](#)
26. Ryu G, Seo MY, Lee KE, et al. **Clinical course of rhinosinusitis and efficacy of sinonasal evaluation in kidney transplant recipients: review of 1589 patients.** *Eur Arch Otorhinolaryngol* 2018;275:1183–88 [CrossRef Medline](#)
27. Shibuya T, Momin F, Abella E, et al. **Jerome W. Thompson—UNRELATED: Employment: Sinus disease in the bone marrow transplant population: incidence, risk factors, and complications.** *Otolaryngol Head Neck Surg* 1995;113:705–11 [CrossRef Medline](#)
28. Bartley DL, Hughes WT, Parvey LS, et al. **Computed tomography of hepatic and splenic fungal abscesses in leukemic children.** *Pediatr Infect Dis* 1982;1:317–21 [CrossRef Medline](#)
29. Billings KR, Lowe LH, Aquino VM, et al. **Screening sinus CT scans in pediatric bone marrow transplant patients.** *Int J Pediatr Otorhinolaryngol* 2000;52:253–60 [CrossRef Medline](#)
30. Arulrajah S, Symons H, Cahoon EK, et al. **Relationship between clinical sinusitis symptoms and sinus CT severity in pediatric post bone marrow transplant and immunocompetent patients.** *Eur J Pediatr* 2012;171:375–81 [CrossRef Medline](#)
31. Kasapoglu F, Coskun H, Ozmen OA, et al. **Acute invasive fungal rhinosinusitis: evaluation of 26 patients treated with endonasal or open surgical procedures.** *Otolaryngol Head Neck Surg* 2010;143:614–20 [CrossRef Medline](#)
32. von Kalle T, Fabig-Moritz C, Heumann H, et al. **Incidental findings in paranasal sinuses and mastoid cells: a cross-sectional magnetic resonance imaging (MRI) study in a pediatric radiology department.** *Rofo* 2012;184:629–34 [CrossRef Medline](#)
33. Tomazic P, Neuschitzer A, Koele W, et al. **Feasibility of routine paranasal sinus CT-scans in preoperative transplant patients.** *Ann Transplant* 2011;16:31–35 [CrossRef Medline](#)
34. Brody AS, Frush DP, Huda W, et al; American Academy of Pediatrics Section on Radiology. **Radiation risk to children from computed tomography.** *Pediatrics* 2007;120:677–82 [CrossRef Medline](#)
35. Nagayama Y, Oda S, Nakaura T, et al. **Radiation dose reduction at pediatric CT: use of low tube voltage and iterative reconstruction.** *Radiographics* 2018;38:1421–40 [CrossRef Medline](#)