Original Investigation

Factors and Labor Cost Savings Associated with Successful Pediatric Imaging without Anesthesia: a Single-Institution Study

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Rationale and Objectives: In pediatric imaging, sedation is often necessary to obtain diagnostic quality imaging. We aim to quantify patient and imaging-specific factors associated with successful pediatric scans without anesthesia and to evaluate labor cost savings associated with our institutional Scan Without Anesthesia Program (SWAP).

Materials and Methods: Patients who participated in SWAP between 2019-2022 were identified. Chart review was conducted to obtain sociodemographic and clinical information. Radiology database was used to obtain scan duration, modality/body part of examination, and administration of contrast. Mann-Whitney U and Chi-Square tests were used for univariate analysis of factors associated with success. Multivariate logistic regression was used to evaluate independent contributions to success. Associated hospital labor cost savings were estimated using salary information obtained through publicly available resources.

Results: Of 731 patients, 698 had successful and 33 had unsuccessful scans (95% success rate). In univariate analysis, older age, female sex, absence of developmental delay, and administration of contrast were significantly associated with successful scans. Multivariate analyses revealed that older age, female sex, and absence of developmental delay were significant independent factors lending toward success. Imaging-related factors were not associated with outcome in multivariate analysis. Estimated labor cost savings were $139,367.80 per year for the medical center.

Conclusion: SWAP had an overall success rate of 95%. Older age, absence of developmental delay, and female sex were independently significantly associated with successful outcome. Cost analysis reveals substantial labor cost savings to the institution compared with imaging under anesthesia.

Key Words: pediatric; MRI; anesthesia; sedation; cost-analysis.

INTRODUCTION

Imaging in the pediatric population can be uniquely challenging due to age-related difficulties with communication and variable abilities to remain motionless for long periods of time. For this reason, pediatric imaging frequently requires the use of sedation or general anesthesia (1,2), especially in the context of magnetic resonance imaging (MRI). Anesthesia in the pediatric population, however, is not entirely without risk, with reported life-threatening complications including anaphylaxis, malignant hyperthermia, and acute respiratory failure (3−6). Additionally, repeated anesthesia exposure can potentially lead to long-term adverse neurodevelopmental outcomes including learning disabilities, with animal models suggesting that anesthetic exposure is associated with apoptotic neuronal cell death and altered neurogenesis (3,5−11). Furthermore, anesthesia increases the length of the imaging appointment, requires coordination with preparatory appointments and post-anesthesia recovery time, and can delay subsequent imaging appointments, thereby reducing the efficiency of patient throughput in the imaging suite (3,5).

Acad Radiol 2023; ■:1–10

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https://doi.org/10.1016/j.acra.2022.12.041

The Scan Without Anesthesia Program (SWAP) at our institution, and variations of this program at other institutions, aims to reduce the number of pediatric patients who require general anesthesia or sedation for imaging (6,12−17). In the SWAP program (Fig 1), multiple interventions are applied to prepare children for successful imaging without anesthesia. Child Life Specialists counsel patients and families on expectations with preparatory phone calls, preimaging instructional movies, practice with mock MRI scanners, and stay with the patient throughout the duration of the scan. Additional age-specific interventions include feed-and-swaddle techniques for infants, late-night scanning for children to coincide with sleep times, noise-reduction headphones, child-friendly MRI environments, and movie video goggles for older children. Abbreviated, tailored imaging protocols with noise-reduction sequences are also employed (6,12,16,18−27). As opposed to sedation, however, SWAP requires active caregiver preparation and participation and therefore demands more time and emotional investment from caregivers.

Although many similar programs exist in pediatric hospitals, there is limited literature on patient and imaging-specific factors that influence successful scans without anesthesia (12,16,17,28) as well as analysis of cost savings of SWAP programs. In our study, we seek to quantify the demographic, clinical, and imaging factors associated with successful SWAP scans, and to perform a labor cost analysis associated with the program. We hypothesize that specific factors will lend toward greater likelihood of imaging success, and understanding these factors will facilitate the adoption and implementation of similar programs at other institutions.

MATERIALS AND METHODS

Scan without Anesthesia Program

The SWAP program at our institution is similar to other existing nonsedated pediatric imaging programs described in the literature (12−17,28). At our tertiary-care university-affiliated medical center, we perform approximately 4600-5500 scans per year, based on available data between 2019-2021. All pediatric imaging studies are performed at the pediatric hospital. At our institution, SWAP is available weekdays from 8am-8pm, based on the availability of our Child Life Specialists. SWAP candidates are referred by clinical providers at the time of imaging request and referrals are reviewed by the Child Life Specialists team for candidacy (Fig 1). Over the years, the SWAP program has performed outreach to clinical providers in the form of emails and promotional fliers to raise awareness of the program and increase referrals. Currently, there are 23.6 referrals to SWAP per month on average, with a trend toward increasing referrals (Fig 2A).

A Child Life Specialist will conduct an initial phone screening with caregivers to assess for patient candidacy. For the feed and-swaddle technique, candidates are felt to be less suitable for SWAP if they are older than 6 months of age, do not have a consistent feeding or sleep routine, and have

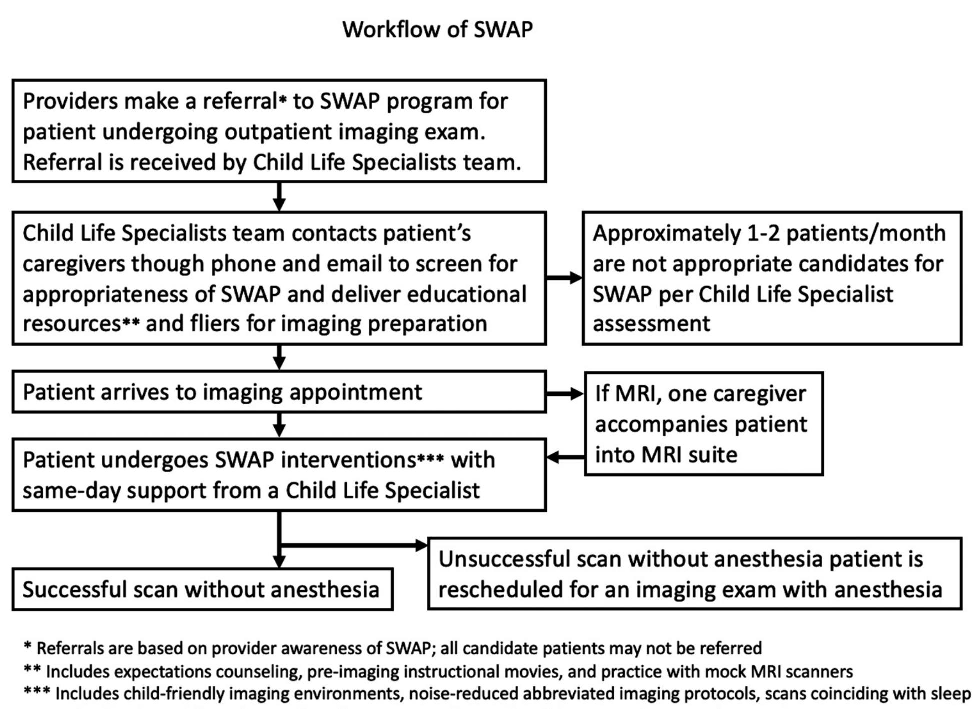

Figure 1. Scan Without Anesthesia Program (SWAP) workflow begins with a provider referring a patient to the Child Life Specialists team. The Child Life Specialists team subsequently contacts the patient's caregivers to screen for appropriateness of SWAP and to provide educational resources to prepare the patient for imaging. On the day of the imaging examination, patients receive one or more SWAP interventions. Patients who are unsuccessfully scanned with SWAP are rescheduled for imaging with anesthesia.

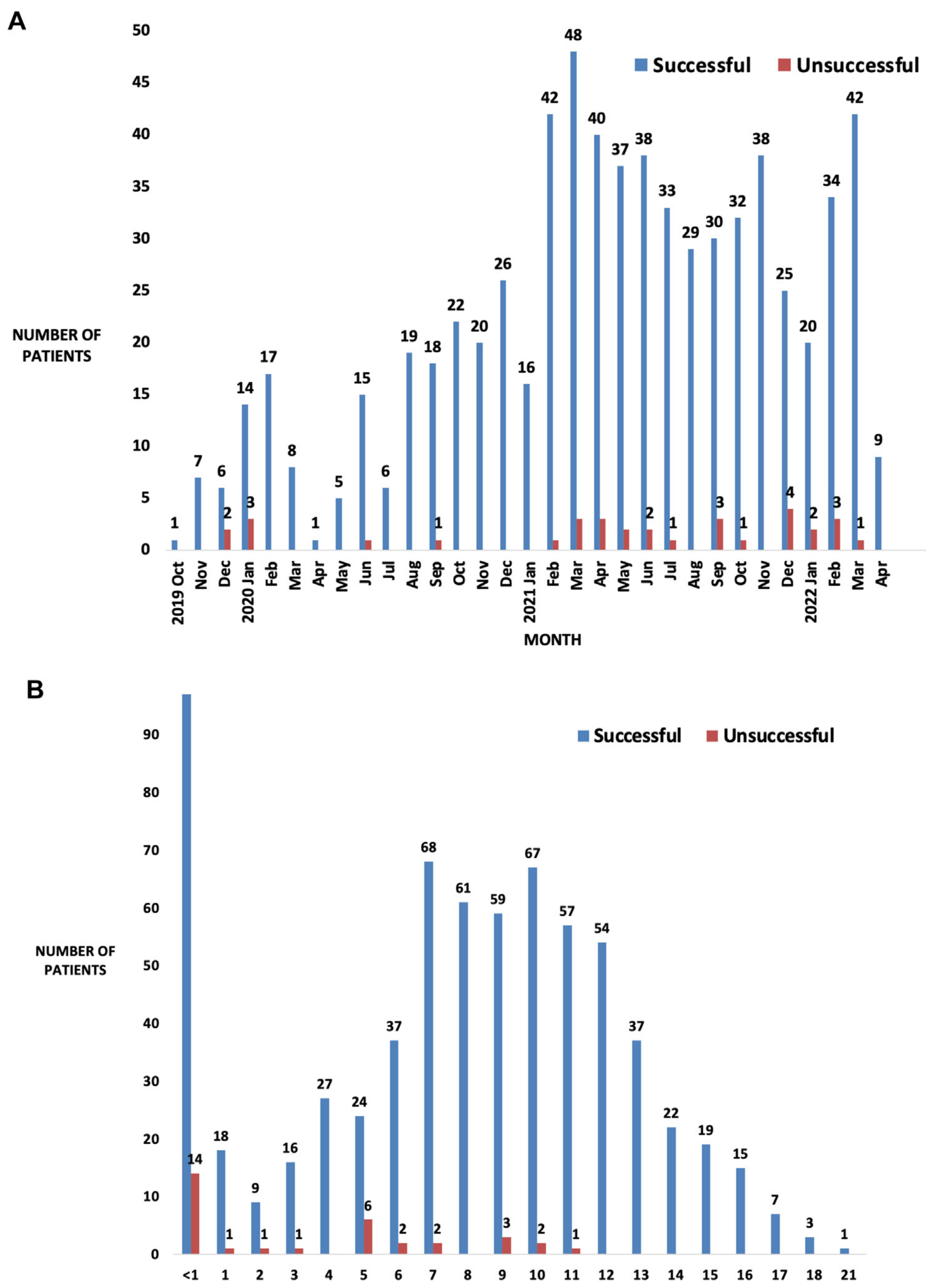

Figure 2A. Number of successful and unsuccessful SWAP scans by month between October 2019 and April 2022. The number of patients imaged under SWAP per month has increased over the duration of the program, due to greater awareness of the program and increased efficiency of throughput. **Figure 2B.** Between Oct 2019 and Apr 2022, patients who were successfully and unsuccessfully scanned had a median age of 8 (IQR 3-11) and 3 (IQR=0.4-6) years, respectively. No patients older than 11 years had unsuccessful scans. The higher number of total patients in the <1 year age category reflects large number of feed-and-swaddle patients imaged for immediate perinatal indications or term-corrected MRI for preterm infants.

heightened sensitivity to noise. Amongst older children, less suitable candidates have severe claustrophobia, severe trypanophobia, motor tics or other involuntary movements, and some seizure disorders. Candidate appropriateness is subjectively determined by Child Life Specialists based on experience, using medical record notes and screening phone calls as guidance, and taking into account priority and urgency of scan, as well as type of scan.

Patients who are considered appropriate SWAP candidates are sent preparatory materials prior to the appointment, including informational brochures and preparatory videos. Upon arrival for their appointment, patients and families meet with

Child Life Specialists. Older patients will may receive video goggles and a movie of their choice. Younger patients may be imaged at times that coincide with their natural sleep. Abbreviated protocols are often employed, with prioritization of essential sequences in the protocol and use of noise reduction sequences, planned in coordination with the radiologists.

Patients who do not successfully complete imaging with SWAP will require a follow-up appointment for imaging with anesthesia. Anesthesia is performed by our institution's pediatric anesthesia team, who evaluates the patient for appropriate level of sedation.

Subjects

Using institutional Child Life Specialist records, we identified 743 pediatric patients who participated in SWAP between Oct 2019 and Apr 2022. We excluded patients with missing or restricted medical records (N=12), from which demographic and clinical information could not be obtained. Scans of all imaging modalities and indications were included. Our final study population included 731 patients. Successful scans were defined as the completion of an imaging protocol to a sufficient degree and quality to answer the clinical question, without the need to schedule an additional repeat imaging exam under anesthesia, as assessed by the interpreting radiologist. A scan was defined as unsuccessful if the interpreting radiologist determined that the scan was not sufficiently diagnostic, due to motion, to answer the clinical question and thus recommended the patient repeat imaging with anesthesia. In such cases, the Child Life Specialists team was notified of the unsuccessful study and the outcome was documented in internal Child Life Specialist records. We additionally investigated whether patients with unsuccessful studies returned for imaging under anesthesia.

Subject Demographic and Radiology Information

Chart review of electronic health records was conducted to obtain sociodemographic information of age, sex, self-identified race/ethnicity, preferred language, and history of developmental delay. Subtypes of developmental delay (speech delay, gross motor delay, global developmental delay, unspecified delay, and other [including fine motor, cognitive and multi-domain delay]) were categorized based on chart review and review of pediatric neurology notes. Corresponding radiology database records were reviewed, and information was collected regarding scan duration, imaging modality, body part imaged, and administration of contrast.

Labor Cost Analysis

Cost analysis was performed for MRI with SWAP vs. anesthesia, including specialist labor costs from the hospital perspective. Cost analysis focused on MRI as opposed to other modalities, since MRI constituted the majority of SWAP studies. Based on input from the institution's nursing supervisor, MRI technologist supervisor, pediatric anesthesia director, and Child Life Specialists team, the average time spent pre-imaging, during the imaging, and post-imaging, assuming a 1.5-hour MRI, was calculated for the MRI technologist, nurse, Child Life Specialist, and anesthesiologist based on institutional practice records. The average hourly rate of labor costs for each specialist was compiled through public records with hourly rates based on a job code's mid-tier rate (29,30). The total labor cost savings per successful MRI exam with SWAP compared to with anesthesia was calculated as the difference in total labor cost per case.

The cost of the MRI-compatible audio/visual goggle system was not included in this cost analysis, as it was not considered a recurrent cost, but is provided as supplemental information, as it remains a cost consideration in implementation of this program.

Statistics

Mann-Whitney U tests and Chi-Square tests were used for univariate analysis to compare factors between patients with successful and unsuccessful scans without anesthesia. Analysis was performed in GraphPad Prism 8 (GraphPad, San Diego, USA). Statistical significance is set at $p<0.05$. For multivariate analysis, backward elimination multivariate logistic regression was performed on factors meeting statistical significance to $p<0.10$ using R (31).

IRB Approval

This retrospective cohort study is Health Insurance Portability and Accountability Act compliant and approved by the local Institutional Review Board (Study Number: 18-25412, approved June 2019).

RESULTS

Patient-Specific Factors

The final population in the SWAP program included 698 patients with successful scans and 33 patients with unsuccessful scans, constituting a 95% success rate (Table 1, Fig 2A). Of unsuccessful studies, 18/33 (55%) returned for repeat imaging under anesthesia. Median age at time of SWAP was 8 years (interquartile range [IQR] 3-11) for successful scans, and 3 years (IQR 0.4-6) for unsuccessful scans ($p<0.01$, Fig 2B). Of unsuccessful scans, 72.7% were male and 27.3% were female ($p=0.01$, Table 1). There was no difference in success rate with regards to self-reported preferred language (English, Spanish, Other, $p=0.44$, Table 1) or race/ethnicity (Asian, Black, Hispanic, Multiethnic, Non-Hispanic White, Other, Unknown, $p=0.82$, Table 1). A history of developmental delay was associated with unsuccessful scans ($p<0.01$, Table 1). Subtypes of developmental delay were not significantly different between successful and unsuccessful scans $p=0.77$, Table 1).

TABLE 1. Patient Demographic and Clinical Factors Analyzed in Relation to SWAP Outcome Over the Duration of the Program

		Successful (N=698)	Unsuccessful (N=33)	Rate of Success	*p*-value
Age (Yrs) [Median (IQR)]		8 (5.0-11.0)	3 (0.4-6.0)		<0.01
Sex					<0.01
	Female	375 (53.7%)	9 (27.3%)	375/384 (97.7%)	
	Male	323 (46.3%)	24 (72.7%)	323/347 (93.1%)	
Preferred language					0.44
	English	611 (87.5%)	27 (81.8%)	611/638 (95.8%)	
	Spanish	80 (11.5%)	6 (18.2%)	80/86 (93.0%)	
	Other language*	7 (1.0%)	0 (0%)	7/7 (100%)	
Self-reported race/ethnicity					0.82
	Asian	53 (7.6%)	4 (12.1%)	53/57 (93.0%)	
	Black	23 (3.3%)	1 (3.0%)	23/24 (95.8%)	
	Hispanic	198 (28.4%)	11 (33.3%)	198/209 (94.7%)	
	Multiethnic	44 (6.3%)	1 (3.0%)	44/45 (97.8%)	
	Non-Hispanic White	261 (37.4%)	13 (39.4%)	261/274 (95.3%)	
	Other**	74 (10.6%)	2 (6.1%)	74/76 (97.4%)	
	Unknown	45 (6.4%)	1 (3.0%)	45/46 (97.8%)	
History of developmental delay					<0.01
	Absent	492 (70.5%)	16 (48.5%)	492/508 (96.9%)	
	Present	206 (29.5%)	17 (51.5%)	206/223 (92.4%)	
Subtypes of developmental delay					0.77
	Speech Delay	81 (39.3%)	9 (52.9%)	81/90 (90.0%)	
	Gross Motor Delay	26 (12.6%)	2 (11.8%)	26/28 (92.9%)	
	Global Delay	34 (16.5%)	2 (11.8%)	34/36 (94.4%)	
	Unspecified Delay	35 (17.0%)	3 (17.6%)	35/38 (92.1%)	
	Other Delay***	30 (14.6%)	1 (5.9%)	30/31 (96.8%)	

IQR, interquartile range; SWAP, Scan Without Anesthesia Program; YRS, Years
* Includes American Sign Language, Chinese-Cantonese, Chinese-Mandarin, Punjabi, and Igbo
** Includes self-reported Other/ American Indian or Alaskan Native/ Other Pacific Islander
*** Includes fine motor, cognitive, and multi-domain delay

Imaging-Specific Factors

On univariate analysis, contrast administration was significantly associated with SWAP success (42% of successful scans vs. 24% of unsuccessful scans, p=0.04, Table 2). Scan duration did not significantly affect success, although median scan time was longer for unsuccessful scans (62 minutes) vs. successful scans (54 minutes, p=0.31, Table 2). Modality of imaging (MRI, computed tomography [CT], other) was not significantly associated with success, although CT demonstrated the highest rate of success (97%, p=0.07, Table 2). The distribution of scan type, as defined by modality and body part imaged, was significantly different between successful and unsuccessful scans (p<0.01, Table 3). This difference is accounted for by a 100% success rate of some scan types (Magnetic Resonance (MR) orbit, MR Pituitary, MR Rapid Brain, MR Whole body), but lower rates of success in other scan types (MR Brain Without Contrast, MR Face/Neck, CT abdomen/pelvis, and MR Internal Auditory Canal).

TABLE 2. Imaging-Related Factors Analyzed in Association with SWAP outcome

		Successful (N=698)	Unsuccessful (N=33)	Rate of Success	*p*-value
Contrast enhanced					0.04
	Yes	294 (42.1%)	8 (24.2%)	294/302 (97.4%)	
	No	404 (57.9%)	25 (75.8%)	404/429 (94.2%)	
Scan duration[a] (min) [Median (IQR)]		54 (40-74)	54 (39-93)		0.31
Modality of study					0.07
	MRI	585 (83.8%)	28 (84.8%)	585/613 (95.4%)	
	CT	98 (14.0%)	3 (9.1%)	98/101 (97.0%)	
	Other*	15 (2.5%)	2 (6.1%)	15/17 (88.2%)	

IQR, interquartile range; min, minutes; SWAP, Scan Without Anesthesia Program
a Scan duration available in 679 patients with successful scans and 23 patients with unsuccessful scans.
* Includes interventional radiology, ultrasound-guided biopsy, nuclear medicine studies.

TABLE 3. Imaging Protocols, as Defined by Modality and Body Part Imaged, Ordered by Overall Rate of Success.

Imaging Protocol	Successful (N=698)	Unsuccessful (N=33)	Rate of Success
MR orbit	10 (1.4%)	0 (0%)	10/10 (100%)
MR pituitary	8 (1.1%)	0 (0%)	8/8 (100%)
MR rapid brain	29 (4.2%)	0 (0%)	29/29 (100%)
MR whole body	12 (1.7%)	0 (0%)	12/12 (100%)
Other MRI*	21 (3.0%)	0 (0%)	21/21 (100%)
MR musculoskeletal**	82 (11.7%)	1 (3.0%)	82/83 (98.8%)
MR vessels	48 (6.9%)	1 (3.0%)	48/49 (98.0%)
MR brain with and without contrast	71 (10.2%)	2 (6.1%)	71/73 (97.3%)
MR abdomen	31 (4.4%)	1 (3.0%)	31/32 (96.9%)
MR spine (cervical, thoracic, lumbar, total)	51 (7.3%)	2 (6.1%)	51/53 (96.2%)
MR enterography	48 (6.9%)	2 (6.1%)	48/50 (96.0%)
MR pelvis	18 (2.6%)	1 (3.0%)	18/19 (94.7%)
MR face/naso/neck	26 (3.7%)	2 (6.1%)	26/28 (92.9%)
MR brain without contrast	111 (15.9%)	9 (27.3%)	111/120 (92.5%)
MR rapid spine	4 (0.6%)	1 (3.0%)	4/5 (80.0%)
MR internal auditory canal	14 (2.0%)	6 (18.2%)	14/20 (70.0%)
CT angiogram	8 (1.1%)	0 (0%)	8/8 (100%)
CT brain	10 (1.4%)	0 (0%)	10/10 (100%)
CT heart	10 (1.4%)	0 (0%)	10/10 (100%)
CT lower extremity	4 (0.6%)	0 (0%)	4/4 (100%)
CT Spine (cervical, thoracic, lumbar)	5 (0.7%)	0 (0%)	5/5 (100%)
CT temporal bone	10 (1.4%)	0 (0%)	10/10 (100%)
Other CT***	2 (0.3%)	0 (0%)	2/2 (100%)
CT craniofacial	28 (4.0%)	1 (3.0%)	28/29 (96.6%)
CT chest	18 (2.6%)	1 (3.0%)	18/19 (94.7%)
CT abdomen/pelvis	6 (0.9%)	1 (3.0%)	6/7 (85.7%)
Non-MRI/CT studies****	13 (1.9%)	2 (6.1%)	13/15 (86.7%)

CT, computed tomography.
There was an overall difference in rate of success based on imaging protocol (p-value <0.01).
* Includes BrainNav, Appendix, Temporomandibular Joint, Chest, Heart, Neurogram, Skull Base
** Includes Finger, Hand, Wrist, Forearm Elbow, Humerus, Shoulder, Scapula, Sternoclavicular Joint, Foot, Tib/Fib, Knee, Femur, Hip
*** Includes Neck, Sinuses
**** Includes interventional radiology, ultrasound-guided biopsy, nuclear medicine studies

Multivariate Model

In multivariate logistic regression, older age (odds ratio [OR] 1.22, confidence interval [CI] 1.12-1.34), developmental delay (OR 0.47, CI 0.23-0.96), and female sex (OR 2.56, CI 1.15-5.68) were significantly and independently associated with scan outcome (Table 4). Administration of contrast was no longer significantly associated with outcome.

Labor Cost Analysis

Using SWAP instead of anesthesia for imaging (Table A.1), for an average 1.5-hour scan, the average labor cost savings per case for Clinical Nursing support is $29.97 and for anesthesiologist support is $593.15. Child Life Support for SWAP costs $79.31 more per case. Regardless of SWAP vs. anesthesia, the cost of an MRI technologist for a 1.5-hour exam remained the same. Thus, the total labor cost savings for SWAP instead of anesthesia is $543.82 for each successful case. Over the course of the SWAP program, 698 successful cases totaled a labor cost savings of $379,586.36.

In the 33 unsuccessful cases that required both the initial SWAP appointment and a second appointment under anesthesia, the hospital incurred the cost of two appointments with an additional labor cost of $944.45 per case, totaling $31,166.85 during this time period. Of note, when patients returned for a follow-up appointment under anesthesia, they were not charged for the initial unsuccessful appointment.

In total, the program had a cost savings of $348,419.51 over its 30-month duration or $139,367.80 per year.

The fixed cost of the MRI-compatible audio/video goggle system is provided in Table A.1.

TABLE 4. Factors Associated with Imaging Success in Multivariate Analysis of Patient and Imaging-related Factors

	Odds Ratio (95% CI)	p-value
Age	1.22 (1.12-1.34)	<0.01
Developmental delay	0.47 (0.23-0.96)	0.04
Female sex	2.56 (1.15-5.68)	0.02

DISCUSSION

At our institution, SWAP was created to decrease the medical and sedation risk of anesthesia for imaging exams in pediatric patients, with the added benefit of increasing healthcare value through labor cost savings. At our institution, SWAP has a 95% success rate. Older age, female sex, and absence of developmental delay were independent predictors of successful scans. Multiple other imaging factors including scan duration, modality of imaging, and administration of contrast were not significantly associated with outcome, suggesting that all scans should be considered for inclusion in SWAP trials. Additionally, from a hospital cost perspective, SWAP has produced significant labor cost savings for the institution compared to imaging under anesthesia.

In our study, successful scans were associated with older age, which may reflect increased maturity and tolerance to lengthy scans. This finding aligns with two previously published studies (16,28), although one prior study did not find significant differences in success rates with regard to age (17). Additionally, in our study, female sex was also associated with successful SWAP, which may also be related to relative maturity for age. A previous study found a nonsignificant trend toward higher success rates in female infants (28) while two other studies found no significant difference in success based on sex (16,17). These differences in findings across different studies may be accounted for by differences in age range of the study population, and may also reflect selection bias during the initial SWAP referral and screening process, as there is subjectivity across providers and institutions with regards to which patients are considered suitable for a trial of SWAP.

History of developmental delay significantly reduced the odds of a successful scan, although no difference was found between the distribution of specific developmental delay subtypes. In our program, all children with developmental delay are screened by the Child Life Specialists team prior to the appointment for likelihood of success, thus potentially mitigating the impact of this factor on outcome, which still remained significant. During the screening process for SWAP, Child Life Specialists try to include as many patients as possible and provide realistic adaptations to facilitate success. During preparatory phone calls with caregivers of patients with developmental delay, the Child Life Specialists team will investigate past medical experiences, length of time patient is able to remain still, need for contrast and IV placement, and environmental stressors, which may include room lighting, number of staff present, the feeling of unfamiliar gowns, MRI noises despite ear protection, the number of transitions required prior to entering the MRI scanner room, inability to verbalize needs or communicate with the care team, and ability to access fidget items or weighted blankets. All of these factors are taken into account during the scan appointment to optimize the chances of success. Importantly, we found no difference in success rate based on patients' preferred language and self-reported race/ethnicity, which supports equitable care within the program.

Imaging-related factors were not significantly different between successful and unsuccessful studies. Given the high overall success rate of SWAP, this finding supports the consideration of SWAP for all imaging requests. The use of contrast was associated with success per univariate analysis; however, multivariate analysis did not reveal contrast administration to be significant in the context of additional potentially confounding variables. It is possible that children who are able to tolerate intravenous line placement for contrast administration prior to imaging exams have higher tolerance for scans in general. Additionally, these patients and caregivers arrive for their appointment ahead of schedule for line placement, allowing for additional preparation time prior to the scan. Several studies that do not require intravenous contrast, such as the developmental delay protocol and MRI Internal Auditory Canal (IAC), may have lower success rates due to the clinical indication and study population. We did not detect a significant difference in scan duration between outcome groups, which lends further support that longer examinations are amenable to successful SWAP. Modality of imaging was not associated with success; however, CT exams overall demonstrated higher success rates compared to other modalities, likely due to faster CT acquisition times compared to MRI and ultrasound.

Distribution of imaging protocols, as defined by modality and body part imaged, was significantly different between outcome groups. Some studies such as MR Orbit, MR Pituitary, MR Rapid Brain, and MR Whole Body were universally successful. MR IAC, MR rapid spine, and MR brain without contrast demonstrated the lowest rate of success, which can be explained by a few different reasons. The most common indication for MR IAC is evaluation of sensorineural hearing loss, and thus it is possible that pathologies impairing hearing influence the success of scanning without anesthesia (32). As the MR IAC is inherently designed to evaluate small structures in the inner ear and internal auditory canal, the standard for successful outcome is much higher, as any degree of motion will obscure the evaluation of size and presence of the cochlear nerve. Similarly, the MR rapid spine was designed for a rapid evaluation of conus position and presence of spinal dysraphism, but small anomalies may not be detectable in the setting of motion, and thus these patients will return for sedated studies if there is high clinical or imaging suspicion. Many children imaged for these two types of studies also tend to be younger, and younger age is associated with unsuccessful outcome in our study. MR Brain Without Contrast also had a lower success rate compared to MR Brain With And Without Contrast (92.5% vs. 97.3%, respectively), which may be due to a common indication for the noncontrast study being workup of developmental delay. The presence of developmental delay was associated with unsuccessful outcome in our study. In contrast, MR Rapid Brain had the highest rate of success (100%) due to the relatively short duration of the scan and relative interpretive tolerance to motion-degradation when assessing for changes in ventricular size. Other non-MRI and non-CT imaging studies encompassing interventional radiology, ultrasound-guided biopsies, and nuclear medicine studies had a lower success rate (15/17, 87%). The two unsuccessful cases were nuclear medicine studies; this is possibly due to the lengthy duration patients need to remain still during the acquisition of nuclear medicine studies. Interventional radiology procedures such as percutaneous nephrostomy tube exchanges and ultrasound-guided biopsies had 100% success rate despite procedure-related stimulation.

From the hospital perspective, SWAP produces substantial labor cost savings for the institution. Another institution reports a total cost savings of $241.82 per hour in anesthesiologist and nursing staff salaries after subtracting Child Life Specialist salary when comparing exams with and without anesthesia (13). While these figures are not directly comparable across the country due to regional variations in cost and salary, our study supports existing literature that SWAP promotes labor cost savings for the institution.

As imaging studies are reimbursed based on Current Procedural Terminology codes, regardless of specific sequences (i.e., MR Rapid Brain and MR Brain Without Contrast are reimbursed the same, under the same Current Procedural Terminology code), increased efficiency of imaging through shortened protocols should not negatively impact departmental reimbursement for the imaging study.

Additional indirect cost savings include increased efficiency of imaging throughput: making additional MRI appointments available due to shorter imaging duration with SWAP vs. anesthesia, filling more after-hours and evening imaging appointments where the MRI would otherwise be unused, and reducing risk of short and long-term complications from anesthesia for the patient. Quantifying these benefits to imaging efficiency will be the subject of future work in this field.

Patient who required repeat imaging with anesthesia were not billed for the initial appointment, so SWAP comes at no additional financial cost to the patient. SWAP, however, does require additional time and emotional investment from caregivers, with longer preparation time immediately prior to imaging and need for increased caregiver engagement throughout the process. Additionally, 45% of unsuccessful SWAP patients who required imaging with anesthesia did not return for repeat imaging, for a variety of reasons, with potential impact on timeliness of care. Ultimately, however, improving the patient experience improves customer satisfaction and return for care for the hospital system.

In this paper, we analyze a large single-institutional experience with scanning without anesthesia, but our study does have limitations. This study is retrospective and observational, conducted at a single institution which limits generalizability to other institutions, however, includes the entire population of SWAP enrollees since the program's recorded conception. The small sample size of the unsuccessful group limits detection of statistical differences; however, the overall high rate of success for SWAP is a testament to the efficacy of this program. Importantly, at our institution, SWAP does not screen all potential anesthesia cases for SWAP eligibility. Referrals are based on provider awareness and preference, thus potentially introducing selection bias based on referral to the program. Furthermore, not all patients referred for SWAP are ideal candidates based on Child Life Specialist assessment; however, often only one to two patients per month are declined after screening. As such, the high rate of success may reflect an element of bias, however, the program was designed to optimize the chances of successful scans. As patients sometimes receive care in other healthcare systems, we were unable to analyze for differences between those who were receiving SWAP imaging for first-time imaging in comparison to those who had prior imaging under anesthesia. In our cost analysis, we assumed anesthesia labor was consistently delivered by an anesthesiologist rather than a certified registered nurse anesthetist, which may overestimate cost savings. More comprehensive cost analysis will need to take into account the impact of increased imaging efficiency, changes in ordering patterns, and revenue, and will be the subject of future research. Further research is also required to understand the influence of specific Child Life Service techniques on imaging outcomes and to validate this experience across different hospital systems.

We found a high overall rate of success (95%) with scanning without anesthesia. Patient factors associated with successful scans include older age, female sex, and absence of developmental delay. Imaging-related factors such as modality, scan duration, and administration of contrast were not associated with outcome, suggesting that all scans are amenable for trial without anesthesia. Cost analysis reveals substantial labor cost savings of $139,367.80 per year for the medical center. We hope that this analysis will help to promote the creation of similar programs in hospitals across the country.

ACKNOWLEDGEMENTS

The authors wish to acknowledge and thank Devin Dixon, CRA and Christopher Lam, BS of Radiology Operations for their assistance with anesthesia procedural codes and cost analysis in this paper.

APPENDIX A

See Table A.1.

TABLE A.1. Labor Costs From the Hospital Perspective for Anesthesia or SWAP MRI Assuming a Standard 1.5-hour MRI

With Anesthesia	Full Time Equivalent (FTE)*	Hourly Rate	Hours per Prep	Hours per Procedure	Hours per Post	Total Hours Per Case	Labor Expense	Benefit Markup	Total Cost Per Case
MRI Tech: 9021 RADLG TECHNO PRN	1.00	$72.13	0.00	1.50	0.00	1.50	$108.20	1.34	$144.98
RN: 9139 CLIN NURSE II	1.00	$89.49	0.50	0.50	0.50	1.50	$134.24	1.34	$179.87
Child life: 7873 CHILD LIFE SPEC 1 EX	1.00	$39.46	0.25	0.25	0.00	0.50	$19.73	1.34	$26.44
Anesthesiologist:	1.00	$177.06	0.50	1.50	0.50	2.50	$442.65	1.34	$593.15
TOTAL LABOR COST									**$944.45**

Scan Without Anesthesia Program (SWAP)	Full Time Equivalent (FTE)*	Hourly Rate	Hours per Prep	Hours per Procedure	Hours per Post	Total Hours Per Case	Labor Expense	Benefit Markup	Total Cost Per Case
MRI Tech: 9021 RADLG TECHNO PRN	1.00	$72.13	0.00	1.50	0.00	1.50	$108.20	1.34	$144.98
RN: 9139 CLIN NURSE II	1.00	$89.49	0.50	0.50	0.25	1.25	$111.86	1.34	$149.90
Child Life: 7873 CHILD LIFE SPEC 1 EX	1.00	$39.46	0.50	1.50	0.00	2.00	$78.92	1.34	$105.75
Anesthesiologist:	1.00	$177.06	0.00	0.00	0.00	0.00	$0.00	1.34	$0.00
TOTAL LABOR COST									**$400.63**

SWAP Long-term Investments	Fixed Cost
Standard MRI audio/visual goggle system	$41,000
Advanced MRI audio/visual goggle system with functional paradigm options	$81,000

* Full time equivalent.

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