Decreased Need for Anesthesia during Ultra-Fast Cranial MRI in Young Children: One-Year Summary

Vermeidung von Sedierungen bei Säuglingen und Kleinkindern durch ultraschnelle kraniale MRT: Résumé des ersten Jahres

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ZUSAMMENFASSUNG

Ziel Durch schnelle, der Echtzeit-MRT entlehnten Volume-Coverage-Sequenzen kann das gesamte Gehirn innerhalb weniger Sekunden abgebildet werden. Durch die ultraschnelle Akquisition von 30 ms pro Schicht führen selbst Makrobewegungen der Kinder nicht zu bewegungsbedingten Bildartefakten. Es ist erwartbar, dass sich mit der Implementierung dieser Sequenzen in ein Echtzeit-MRT-Protokoll (RT-cMRT) der Sedierungsbedarf bei Kleinkindern und Säuglingen verringert. Das Ziel dieser Studie war, das Ausmaß des Rückgangs an Sedierungsuntersuchungen nach Einführung eines neuen RT-cMRT-Protokolls zu quantifizieren.

Material und Methoden Es wurden retrospektiv alle cMRT-Untersuchungen eines Jahres bei Kindern unter 6 Jahren nach Einführung der RT-cMRT (2019/2020) mit einer gleichen Zeitspanne vor der Umstellung (2017/2018) verglichen. Es wurde die Häufigkeit von Untersuchungen mit oder ohne Sedierung erfasst und die Zahl an Wiederholungsuntersuchungen sowie die Effektivität der RT-cMRT bestimmt.

Ergebnisse Die Einführung der RT-cMRT ging mit einem deutlichen Rückgang des Anteils an Sedierungsuntersuchungen von 92 % auf 55 % einher. Nur 2 % der RT-cMRT-Untersuchungen waren insuffizient und benötigten im Anschluss noch eine konventionelle MRT. Durch die leichte Verfügbarkeit der RT-cMRT wurden 1,4 statt bisher nur 1,3 Untersuchungen pro Kind und somit mehr Follow-up-Untersuchungen durchgeführt.

Schlussfolgerung Mit innovativer Echtzeit-MRT ist es möglich, bei Säuglingen und Kleinkindern die Zahl an Sedierungen für kraniale MRT – bei geeigneten Erkrankungen – drastisch zu reduzieren. Jedoch sind hierfür neben der Auswahl geeigneter Indikationen auch Anpassungen der Arbeitsabläufe in der radiologischen Abteilung vonnöten.

Kernaussagen:

- Echtzeit-MRT-Sequenzen sind kaum anfällig für Patientenbewegungen.
- Der Einsatz von kranialer Echtzeit-MRT kann Kindern Sedierungen ersparen.
- Durch den niedrigschwelligen Zugang kommt es zu häufigeren Follow-up-Untersuchungen.

ABSTRACT

Purpose Rapid volume coverage sequences based on real-time MRI allow for scanning of the entire brain within a few seconds. Movements of children become almost irrelevant due to the ultra-fast acquisition of 30 ms per slice. The adoption of these sequences in a real-time cranial MRI protocol (RT-cMRI) is expected to reduce the frequency of examina-

tions requiring anesthesia in infants and toddlers. The aim of the study was to quantify the reduction in the number of anesthesia examinations in young children after the implementation of the new RT-cMRI protocol.

Materials and Methods All cMRI studies of children up to 6 years in the first 12 months after the establishment of the RT-cMRI 2019/2020 were retrospectively compared to a matched group of the same period in 2017/2018. The frequency of examinations under anesthesia vs. non-sedation examinations was analyzed. In addition, the number of follow-up examinations and the effectiveness of RT-cMRI was determined.

Results The launch of RT-cMRI led to a significant decrease in the proportion of cMRI under anesthesia from 92 % to 55 %. Only 2 % of the RT-cMRI failed and required conventional MRI under sedation in the follow-up. The speed and ease of use of RT-cMRI increased the number of follow-up examinations from 1.3 to 1.4 examinations per child.

Conclusion This innovative real-time MRI examination allows a drastic reduction in the number of studies under anesthesia for suitable cranial pathologies in children under 6 years. However, cautious selection of indications as well as adjustments to the workflow in the radiological department are required.

Key Points:

- Real-time MRI sequences are almost unaffected by patient movement
- The application of real-time cranial MRI can spare children from sedation
- Low-threshold access results in more frequent follow-up examinations

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Introduction

The great potential of real-time MRI (RT-MRI) applications in routine pediatric radiology was recently reported [1]. With this technology, T1, PD, or T2-weighted images can be acquired as fast as 20 ms per frame. The resulting low vulnerability to movement artifacts makes real-time MRI sequences particularly attractive for the imaging of infants and toddlers. In particular, in addition to rapid and accurate mapping of the T1 relaxation time [2], the T2-weighted volume coverage (VC) technique has already proven to be very effective for brain studies [3], despite its lower spatial resolution and tissue contrast. In brief, the method employs an undersampled radial gradient-echo sequence with SSFP contrast which sequentially acquires a series of shifted but highly overlapping slices in combination with nonlinear inverse image reconstruction with spatial regularization to a neighboring slice. For a temporal resolution of only 50 ms per slice, macroscopic movements are largely frozen [4]. Technical details have been described elsewhere [5].

Until the availability of this real-time MRI technique in our department in September 2019, children up to 6 years of age were usually examined under sedation. Only in highly cooperative children or infants in the first 3 months, who were immobilized by the "feed-and-wrap" technique, sedation was not required [6]. For more than a year now, a novel, ultrafast protocol based on VC sequences for cranial MRI (cMRI) in infants and toddlers without anesthesia has been established in our department for routine diagnostics.

Since the ultrafast VC technique is derived from dynamic real-time MRI sequences, the protocol has been termed cranial real-time MRI (RT-cMRI). So far, this RT-cMRI protocol has been used almost exclusively for assessment alterations of the internal and external cerebrospinal fluid spaces before and after neurosurgical interventions. Rarely, RT-cMRI was employed to rule out relevant bleeding or gross brain parenchyma disorders. An example of the RT-VC sequences is shown in ▶ **Video 1**.

It is not yet clear whether the implementation of this new technique in clinical work in pediatric radiology leads to a decline in the number of studies under anesthesia and whether it has implications for the workflow in a large pediatric radiology department.

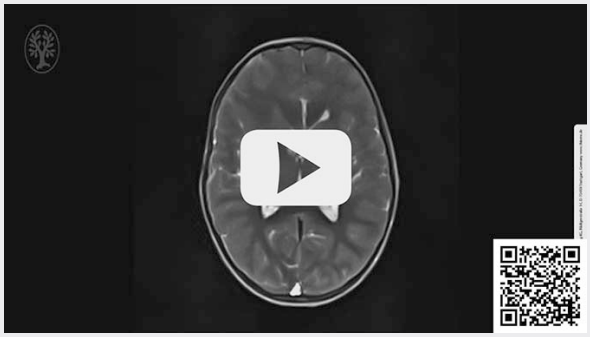
While the performance of real-time T2 VC sequences compared to conventional T2 sequences has been assessed elsewhere [3], this study is intended to evaluate the impact of the implementation of the RT-cMRI protocol on the absolute and relative number of sedation examinations in our department after the first year of its application. Our hypothesis is that the number of MRI examinations under anesthesia in the age group 0–6 years has decreased significantly with the implementation of the RT-cMRI.

Materials and methods

Patients and grouping

The study was approved by the local ethics committee. In this retrospective study, all cMRI studies of children from birth to 6 years of age, which were performed in our department between 2017 and 2020, were identified via the internal radiology information system. The 12-month period after the introduction of the RT-cMRI (post-VC) from November 2019 to October 2020 was compared to the corresponding period from November 2017 to October 2018 (pre-VC). The spectrum of patients was representative for a tertiary care center with pediatrics, neonatology, pediatric surgery, and pediatric neurosurgery. Since the objective of this study was the reduction of examinations under anesthesia rather than the performance of the RT-cMRI sequences for differ-

OP-VIDEO



▶ **Video 1** Video of the T2-weighted VC sequence, an essential component of the RT-cMRI protocol, at actual scanning speed. There are 3 orthogonal planes in a nearly 5-year-old boy with status post-fenestration of a right temporal arachnoid cyst. Note the low susceptibility to movements at second 32. The fastness of the video equals the actual acquisition time of the sequence.

▶ **Video 1** Video einer T2-gewichteten VC-Sequenz in 3 Ebenen als ein zentraler Bestandteil des RT-cMRT-Protokolls. Das Beispiel zeigt einen fast 5 Jahre alten Knaben mit Zustand nach Fensterung einer rechtstemporalen Arachnoidalzyste. Bemerkenswert ist die geringe Anfälligkeit gegenüber Makrobewegungen, z. B. bei Sekunde 32. Die Geschwindigkeit entspricht der tatsächlichen Akquisitionszeit.

ent diseases, a more detailed listing of the individual indications was not undertaken. Sub-analysis was performed for children under one year of age.

MRI protocol

All cMRI examinations in the pre-VC group (2017/2018) were performed on a 3 T Siemens Trio TIM (Siemens, Erlangen, Germany) with a 32-channel head coil.

The studies in the post-VC group (2019/2020) were done on a 3 T Siemens Prisma fit (Siemens, Erlangen, Germany). Depending on the age and size of the child, a 16-channel pediatric head coil or a 64-channel head coil was selected.

The RT-cMRI protocol consists of three orthogonal T2-weighted VC sequences of 15 seconds duration each and a fast T1-weighted 3 D sequence with a duration of about 16 seconds. A series of 200 overlapping slices with a thickness of 3 mm was acquired for the VC sequences. The automatic advancement of the slice position per frame (i. e., the spacing between successive/neighboring sections) was 0.45 mm, which corresponds to a slice overlap of 85 %. For each frame, the k-space was covered by 17 radial spokes. With a measuring time for one VC orientation of about 15 seconds, the total scan time of the entire RT-cMRI protocol was about 70 seconds. The sequence parameters for the rt-cMRI protocol are also shown in ▶ **Supplementary Table 1**. The details of the VC sequence have been published elsewhere [3, 5]. An assistant, usually a parent, joined the child in the MRI scanner and stabilized the head with his or her hands. ▶ **Fig. 1a–d** shows a representative slice from each of the four sequences of the RT-cMRI protocol.

Evaluation

It was recorded whether the cMRI examination was performed under sedation or conscious. A standard cMRI protocol was used for all examinations under sedation regardless of the availability of VC sequences. Furthermore, it was determined whether non-sedation examinations were obtained a) with the new RT-cMRI protocol, b) using the standard protocols with “feed-and-wrap” technique, or c) standard protocols by compliance of the infant.

If a patient had multiple examinations in the pre-VC and post-VC period, the number of repeat examinations per patient in both periods was compared. Additionally, the percentage of cases with an insufficient RT-cMRI, as defined as an RT-cMRI examination that required a standard cMRI within the following 30 days for the same indication, was determined.

To investigate the relationship between categorical variables between the pre-VC group and the post-VC group, the Chi-square test was used. Significance was assumed below a value of 0.05. Statistical analysis was performed with Excel (Microsoft, Redmond, USA).

Results

In the period prior to the introduction of RT-cMRI, only 8 % (25 of 353 patients) of the examinations in the age group 0–6 years were carried out without anesthesia. With the availability of the RT-cMRI protocol, 45 % (215 of 476 patients) of all examinations in this age group could be performed without sedation (▶ **Fig. 2**), corresponding to an 8.6-fold increase. More specifically, the results are as follows:

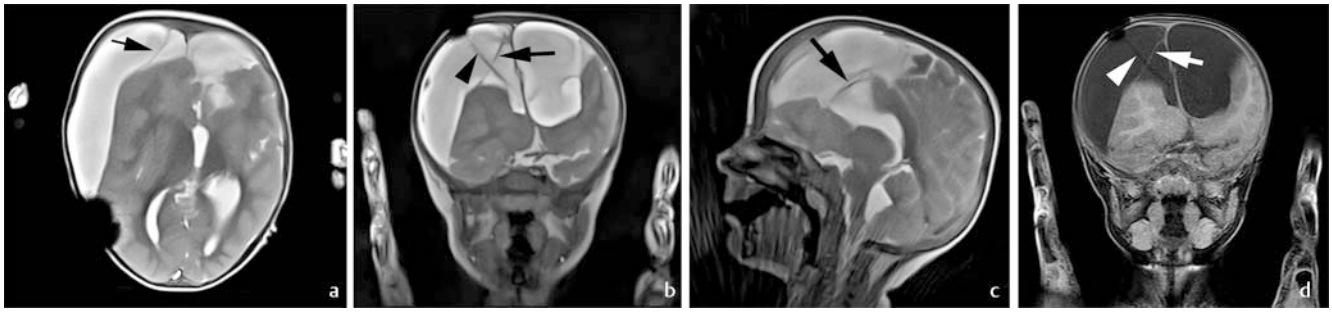
Pre-VC group

In the one-year interval of the pre-VC group, a total of 353 children up to 6 years of age (median age 2.6 years) were examined with a conventional cMRI protocol. The infant subgroup up to 12 months of age included 76 children (0–12 months, median age 0.51 years). The indications for cMRI are listed in ▶ **Table 1**.

Examinations under general anesthesia were performed in 92 % (328 of 353 patients) to yield a diagnostically viable examination (median age 2.5 years). This also largely corresponded to the 93 % portion of examinations (71 of 76 patients, median age 0.52 years) under anesthesia in the subgroup of infants under one year of age. In 25 of 353 patients, examinations were performed without anesthesia: in 5 of 25 patients using the “feed-and-wrap” technique (median age 24 days) and in 20 of 25 patient by cooperation of the infant (median age 5.2 years). Follow-up examinations in the pre-VC reference period were undertaken in 40 of 353 patients, corresponding to a cumulative 119 examinations and an average MRI incidence of 1.29 per child in the entire pre-VC group (median of 58 days between two examinations). The numbers are also shown in ▶ **Supplementary Table 2**.

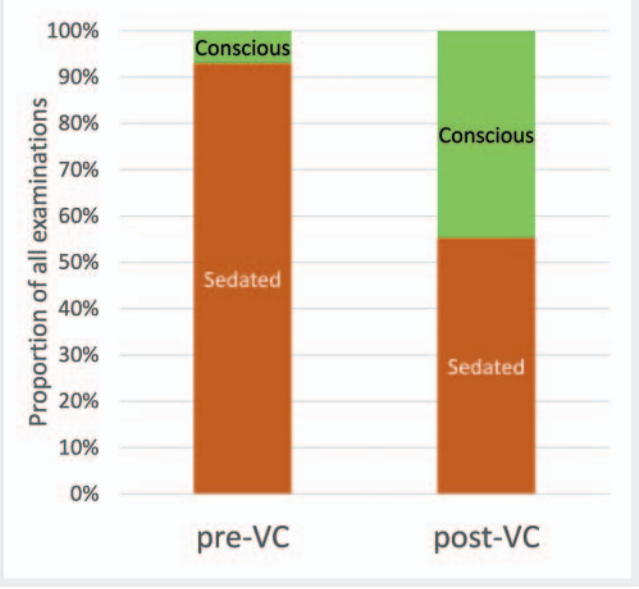
Post-VC group

In the one-year interval following the launch of RT-cMRI, a total of 476 children in the age group 0–6 years (median age 2.4 years) underwent a cMRI examination. Of these, 130 were infants under



▶ **Fig. 1** Representative slices from each of the 4 sequences of the new RT-cMRI protocol in a 2.5-year-old boy with complex brain malformation with open-lip schizencephaly, heterotopias, corpus callosum dysgenesis and hydrocephalus with multiple septa (arrow) with status post-ventriculoperitoneal shunting (arrowhead). The sequences consist of three real-time T2-weighted volume coverage sequences in **a** transverse, **b** coronal, and **c** sagittal orientation, and **a d** coronal T1-vibe Dixon sequence. The total acquisition time of the 4 sequences is 70 seconds (see also ▶ **Video 1**).

▶ **Abb. 1** Repräsentative Schnitte aus allen 4 Sequenzen des neuen RT-cMRT-Protokolls. Bei dem Patienten handelt es sich um einen 2,5 Jahre alten Jungen mit komplexer Hirnfehlbildung mit Open-lip Schizenzephalopathie, Heterotopien, Balkendysgenesie und einem Hydrozephalus mit Septierungen (Pfeil) nach Anlage eines ventrikulo-peritonealen Shunts (Pfeilspitze). Bei den Sequenzen handelt es sich um 3 T2-gewichtete Echtzeit-VC-Sequenzen in **a** transversaler, **b**) koronarer und **c**) sagittaler Orientierung sowie einer **d** koronaren T1-vibe-Dixon-Sequenz. Die Akquisitionszeit der 4 Sequenzen beträgt zusammen 70 Sekunden (s. auch ▶ **Video 1**).



▶ **Fig. 2** Proportional share of cMRI in the age group 0–6 years, divided into examinations with (brown) and without (green) anesthesia in the pre-VC period and the post-VC period.

▶ **Abb. 2** Verhältnis von cMRT-Untersuchungen mit (braun) und ohne (grün) Sedierung in der Altersgruppe von 0–6 Jahren im Prä-VC- und Post-VC-Zeitraum.

one year of age (median age 0.5 years). The indications for cMRI are listed in ▶ **Table 1**.

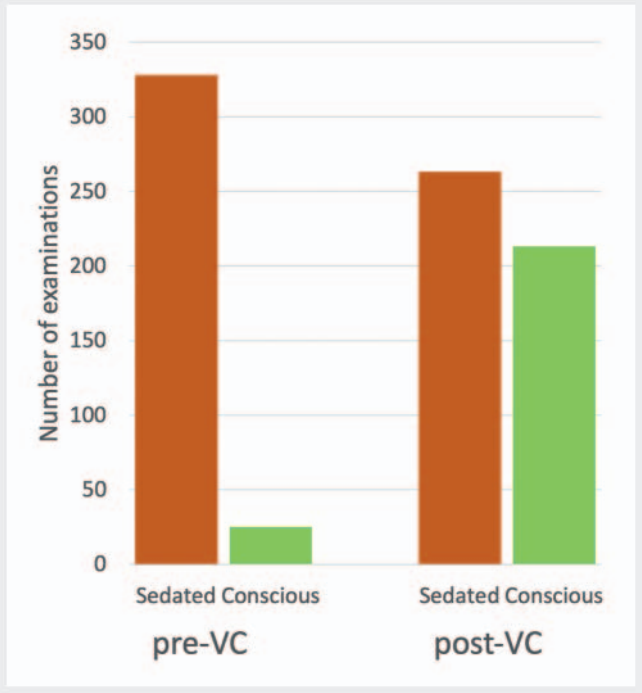
With 55 %, more than half of all cMRI examination in the post-VC group (263 of 476 patients, median age 2.2 years) were still performed under medical sedation (▶ **Fig. 3**). Like the whole group, 52 % of the examinations in the subgroup of infants under one year of age were also carried out under anesthesia (68 of 130 patients, median age 0.5 years).

▶ **Table 1** Indications for cMRI in both cohorts. The increase in the total number of cases is mainly due to the growth in examinations for the assessment of the internal and external cerebrospinal fluid spaces, currently the predominant indication for rt-cMRI.

▶ **Tab. 1** Indikationen für die cMRI in den beiden Kohorten. Die Zunahme der Gesamtfallzahl beruht vor allem auf dem deutlichen Anstieg an Untersuchungen zur Beurteilung der inneren und äußeren Liquorräume, der derzeit wichtigsten Indikation für die kraniale Echtzeit-MRT.

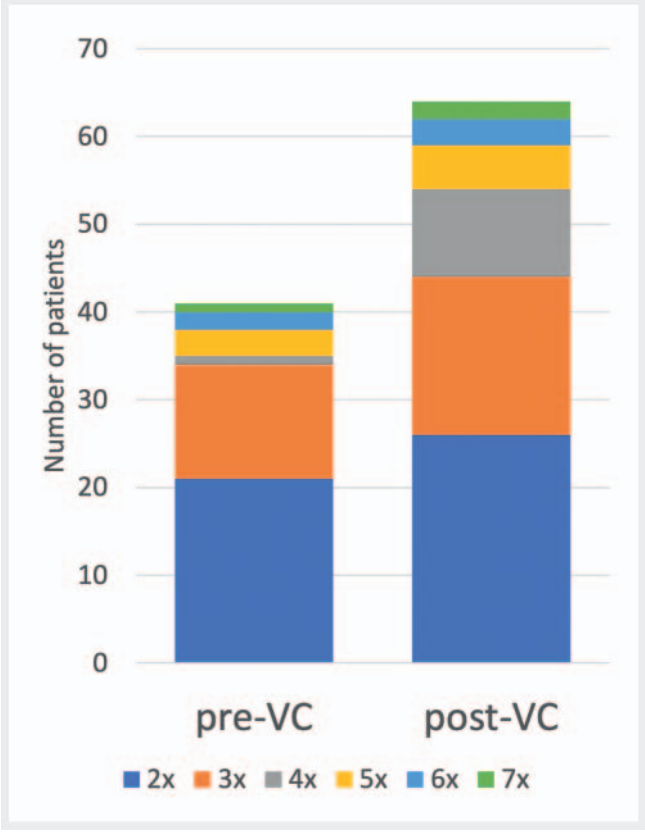
	pre-VC	post-VC
Cerebrospinal fluid spaces	65	183 (+ 118)
Tumor	73	74 (+ 1)
Seizures	48	45 (–3)
Other neurological symptoms	22	31 (+ 9)
Trauma	13	23 (+ 10)
Ocular neurology	17	22 (+ 5)
Neonatal depression	13	16 (+ 3)
Developmental delay	16	16 (0)
Suspected malformation	16	16 (0)
Sensorineural hearing loss	15	12 (–3)
Skull abnormality	16	12 (–4)
Vascular disorder	15	9 (–6)
Pituitary gland	11	7 (–4)
Headache	6	6 (0)
Inflammation	7	4 (–3)
Total	**353**	**476 (123)**

On the other hand, nearly half of the cMRI studies (45 %) were conducted without anesthesia (215 of 476 patients). 87 % of these cMRI examination (187 of 215 patients, median age 2.3 years)



▶ **Fig. 3** Distribution of the total number of cMRI of the pre-VC period and the post-VC period in the age group 0–6 years. A further categorization into studies with (brown) and without (green) anesthesia is illustrated.

▶ **Abb. 3** cMRT-Untersuchungszahlen im Prä-VC- und Post-VC-Zeitraum in der Altersgruppe 0–6 Jahre. Die Zahlen sind in Untersuchungen mit (braun) und ohne (grün) Sedierung unterteilt.



▶ **Fig. 4** Number of patients who received a repeat RT-cMRI examination in the observation period. The different colours indicate the frequency of follow-up examinations per child. The aforementioned subset of patients comprises only 11.3 % and 13.4 % of all patients in the pre-VC and post-VC periods, respectively. In our opinion, the explanation for this increase lies in the current straightforward admission to RT-cMRI. This access is now as convenient as a referral for a cranial ultrasound examination.

▶ **Abb. 4** Anzahl von Patienten, die eine RT-cMRT-Wiederholungsuntersuchung im Beobachtungszeitraum erhielten. Die unterschiedlichen Farben zeigen die Häufigkeit der Follow-up-Untersuchungen pro Kind an. Die genannte Patientenuntergruppe umfasst nur 11,3 % bzw. 13,4 % aller Patienten im Prä-VC- bzw. Post-VC-Zeitraum. Die Ursache dieses Anstiegs liegt nach unserer Meinung in dem aktuell unkomplizierten Zugang zur RT-cMRT.

employed the RT-cMRI protocol. For the remaining children, a standard cMRI protocol was chosen, either using the "feed and wrap" technique (4 of 215 patients, median age 33 days) or simply because the children were older and more cooperative, allowing the use of conventional cMRI without movements (24 of 215 patients, median age 5.3).

In the post-VC group, 64 of 476 children had more than one study in the corresponding period, resulting in a cumulative total of 203 repeat studies (median of 61 days between two examinations). This corresponds to an average MRI rate of 1.41 per child in the entire post-VC group. In only 2 % (4 of 187 patients) of the children with RT-cMRI examination, a follow-up standard cMRI examination under sedation was required during the following 30 days to resolve the clinical issue.

Pre-VC to post-VC group comparison

The frequency of sedation for cMRI decreased from 92 % to 55 % in the age group up to 6 years after the introduction of RT-cMRI (▶ **Fig. 1**), in absolute numbers from 328 to 263 (▶ **Fig. 2**). In infants, a decrease in sedation examinations from 93 % to 52 % was observed. The decrease in the use of anesthesia in both groups after the introduction of RT-cMRI was statistically significant ($p < 0.001$). The number of follow-up examinations was statistically higher in the post-VC group compared to the pre-VC group (▶ **Fig. 4**) ($p < 0.001$).

Discussion

It is unusual to see new diagnostic techniques leading to a rapid transformation in the daily practice in a short period. However, following the establishment of real-time MRI technology in our pediatric radiology department in 2019, we have shown that the rate of examinations under anesthesia during cMRI in children up to 6 years could be reduced by 37 % (41 % for infants) already within the first year.

Anesthetics may have a negative effect on brain development in infants and young children and can result in neurocognitive deficits [7]. Even if the evidence is still ambiguous in humans, the findings of animal studies should be a motivation to reduce the use of anesthetics in infants and young children whenever possible.

In addition to the option of preventing MR artifacts due to the inherent mobility of small children and infants by means of ultrafast sequences, there are several other well-proven approaches to perform a diagnostic cMRI examination without anesthesia in small children [8, 9]. As an example, the "feed-and-wrap" technique is used with a high rate of success in very small children [10], while conditioning of the child before the MRI examination was shown to be effective in older children [11, 12]. A combination of an accelerated standard MRI protocol, conditioning, and immobilization can also yield good results in most cases in specialized departments in almost all age groups [13] and methods of distracting patients are widely used [14].

The key to our RT-cMRI protocol is the novel, motion-robust VC sequence, which allows for coverage of the entire brain within a few seconds. The slice thickness of 3 mm restricts the multiplanar reconstruction in contrast to thin-sliced 3 D sequences. However, since the sequence in our RT-cMRI protocol is performed in 3 orientations within a total measuring time of 45 seconds, any alterations of the cerebrospinal fluid space can be visualized accurately. Furthermore, even if no definite evaluation has been published yet, our experience indicates that larger morphological lesions of the cerebral parenchyma can be detected, comparable to computed tomography and ultrasound in infants with an open fontanelle.

In our protocol, additive T1-weighting is realized by a conventional, fast 3 D sequence. Since blood components are not always visualized in the T2-VC sequence with the required diagnostic accuracy, this is necessary for the assessment of the internal and external CSF spaces [15, 16]. The application of the RT-cMRI protocol achieves a total examination time of not more than 3–5 minutes, mainly depending on the time needed for positioning of the patient and the parent placed in the gantry. This duration is shorter than an ultrasound examination and equally as fast as computed tomography.

Even more important than the reduction of examination time by RT-cMRI is that anesthesia can be omitted in the majority of cases. Thus, potential adverse health effects can be prevented. The reduced number of sedations in cMRI, which can already be observed in the first year of application, also has an economic impact because of (i) the increased cMRI capacity per day due to the significantly shorter examination time, (ii) the relieved, cost-intensive anesthetic capacity, and (iii) the shorter hospital stays of non-sedated children compared to sedated children.

The time saved per examination is beneficial to other children, which is particularly important when MR resources are limited. The additional cost and time savings in anesthesia capacity should be a welcome side effect in almost every clinic. At the same time, since fasting and anesthesia are not needed, delay of urgent examinations may be reduced, enabling faster initiation of therapy in the case of urgent but not immediate indications, such as increased intracranial pressure, thus enabling a significantly faster initiation of therapy.

Important limitations of the method at present are that both spatial resolution and soft tissue contrast in VC sequences do not equal the quality of a conventional T2 turbo-spin-echo sequence. Therefore, RT-cMRI has been used almost exclusively for the assessment of the internal and external CSF spaces, as the effectiveness of this method has previously been demonstrated [3]. In selected cases we also applied the method following minor head trauma or to rule out larger morphological pathologies. Additional limitations of ultrafast cMRI are that it is not possible to generate strong T1 contrasts, cerebrospinal fluid signal suppression (FLAIR) or diffusion weighting, all of which are essential components of full-fledged cMRI. Even given the availability of VC sequences, conventional cMRI will remain the standard in our facility whenever anesthesia could be avoided, either by the "feed-and-sleep" technique or by cooperation of the child. Moreover, the potential and limitations of RT-cMRI beyond the age of 6 years must be evaluated by further studies.

However, the interest and increasing requests from colleagues for a rapid expansion of indications for RT-cMRI also indicate that "quick and easy" RT-cMRI without anesthesia meets real demands of our referring physicians. We found a marked increase in the use of MRI in children with hydrocephalus, requiring surgical intervention. This reflects the high status that neurosurgeons, in particular, attribute to the new technique compared with cranial ultrasound. In fact, by far the largest increase in examinations in the post-VC period is focused on assessment of the internal and external CSF spaces. It is likely that to some degree not only have existing indications now been performed without anesthesia, but also new indications have been created or the threshold for performing cMRI has been lowered.

The limitations of this study are its retrospective approach without matching the two cohorts and omitting variations in the study numbers over the remaining earlier years. The nature and extent of artifacts that occur in the VC sequences were not specifically addressed in this study, as it is intended to focus on the higher-level outcome of reducing sedation for cMRI. Furthermore, an evaluation of VC artifacts in a similar pediatric population has been previously published [3].

To some extent, we have to reject the idea that RT-cMRI in the first year of life is considered a standard imaging procedure or even a substitute for a cranial ultrasound examination. Due to the wide availability and simple set-up, the latter remains the standard examination even after the introduction of RT-cMRI, since the inner and outer cerebrospinal fluid spaces can be sufficiently assessed in a majority of cases when the fontanel is still open. We also want to be careful not to discredit RT-cMRI as a result of inappropriate use and indications.

With the launch of RT-cMRI at our department two things have changed for our Department of Pediatric Radiology over the last 12 months: To improve the workflow, we now schedule at least one hour less per day for standard cMRI and dedicate this time to unscheduled RT-cMRI. As a result, RT-cMRI examinations can now be realized promptly without reservation of specific time slots in advance and without delay due to fasting.

The second benefit of the ultra-fast protocol was significantly less strain on our limited anesthesiologic resources. The evaluation of the internal and external cerebrospinal fluid spaces represents the largest proportion of cMRI indications in our department. Since most of these patients had to be examined under sedation in the past, the introduction of RT-cMRI frees the corresponding anesthesia capacity for other indications. The medical advantage for the children is combined with the concurrent savings of medical resources.

Last, but not least: The satisfaction of the referring clinical colleagues has increased greatly. RT-cMRI is accepted as a new and very attractive imaging technique in pediatric patients. It is now up to us to further develop this new diagnostic option and to offer it based on appropriate indications.

Conclusion

The implementation of real-time MRI in our department has led to a significant reduction in the number of cMRI studies under anesthesia in children up to 6 years of age and thus lowered the threshold for cMRI. In our department, children with alterations of the internal and external CSF spaces in this age group are now almost exclusively scanned using real-time MRI without sedation. However, in order to reach the full benefits of this new method, a careful limitation of indications as well as adjustments to the workflow within the radiological department are essential.

CLINICAL RELEVANCE

- Sedation in young children can have immediate and possibly long-term negative consequences.
- Ultra-fast MRI sequences make it possible to perform cranial MRI without sedation for many indications.
- Through the implementation of real-time cranial MRI and a concomitant adaptation of the workflow in the radiology department, the number of cMRI examinations under anesthesia can be lowered significantly.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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