Print ISSN: 2321-6379
Online ISSN: 2321-595X

Original Article

MRI in Contrary to Conventional Imaging Techniques in Evaluation of Anorectal Malformation

Mahima Rishabh Kapoor

Assistant Professor, K. J. Somaiya Medical College, Mumbai, Maharashtra, India

Abstract

Introduction: Anorectal malformations represent a complex group of congenital anomalies which results in abnormal development of the hindgut. To accomplish a successful post-operative outcome, an accurate preoperative imaging assessment is required.

Purpose: The purpose of this study was to compare the sensitivity of magnetic resonance imaging (MRI) and conventional imaging technique in terms of detection of type of anorectal malformation, type of fistula, development of puborectalis muscle, and external sphincter and associated anomalies taking surgery as reference standard.

Methods: Patients underwent MRI and pressure colostography/fistulography. All patients underwent corrective surgery. The results of MR and conventional techniques were compared using surgery as reference standard.

Results: MRI and colostography/fistulography were able to correctly identify type of ARM in 28 out of 30 patients (93.3%). The sensitivity of MRI and colostography/fistulographyfor detection of presence of fistula was 100% and 37.03%, respectively. MRI and colostography correctly identified type of fistula in 22 out of 27 (81.48%) and 10 out of 27 patients (37%), respectively. Colostography failed to identify 16 surgically proven fistula out of 27 (59.25%). It was possible to clearly visualize and evaluate the bulk of muscles the levatorani and pubo-rectalis muscle in all the patients with MRI. The incidence of associated anomalies in present study was 43.3%.

Conclusion: MRI proved to be better imaging technique than conventional imaging techniques (colostography/fistulography) for pre-operative workup of anorectal malformation.

Key words: Anorectal malformation, Magnetic resonance imaging, Pressure colostography/fistulography

INTRODUCTION

Anorectal malformations comprise a complex group of congenital anomalies that results from abnormal development of the hindgut, allantois, and Mullerianduct resulting in incomplete or partial urorectal septal malformations. ARM is a relatively uncommon congenital cause of intestinal obstruction in the newborn, occurring in approximately one out of every 4000–5000 births (4.05/10,000 births).[1] Approximately 36.4% of cases occur as isolated lesions and 63.6% are associated with other congenital anomalies.[2-6] High lesions are more common among boys (34.5% vs. 13.3%) and low lesions more common among girls (70.9% vs. 47.6%).[7] The male female ratio associated with ARM is almost equal, with a ratio of 56:44.[1,7-9] Associated anomalies are 13 times more common in high type in comparison to low type.[7,10] Several classification systems have been proposed for ARM; however, the Krickenbeck classification is widely accepted today, which is based on the presence or absence of fistula and its location.[11-13] The final stage corrective surgery for anorectal malformation depends on the level of the fistula in reference to pelvic floor. Thus, accurate recognition of different subtypes of ARM is essential for operative management.[11]

Access this article online

www.ijss-sn.com

Month of Submission : 11-2022
Month of Peer Review : 12-2022
Month of Acceptance : 12-2022
Month of Publishing : 01-2023

Since the introduction of various imaging modalities for anorectal malformation such as invertogram, contrast enemas, distal high-pressure colostography, voiding cysto-urethrograms, and recently accepted cross-sectional modalities such as ultrasound, computed

Corresponding Author: Dr. Mahima Rishabh Kapoor, A-1603, Patel Paradise, Sector 35E Kharghar Navimumbai - 410 210, Maharashtra, India.

tomography, and magnetic resource imaging (MRI), all the diagnostic imaging have helped surgeon a lot with the information needed to correct the malformation. To achieve a successful post-operative outcome, a proper pre-operative imaging assessment is required which includes assessment of the presence of a fistula, level and type of anorectal malformation, developmental state of the sphincter muscle complex, and presence of any other associated anomalies.[14] MRI fulfills these requirements because of its excellent intrinsic contrast resolution, multi-planar imaging capabilities, and lack of ionizing radiation. Disadvantages of MRI include the need for sedation, high cost, and limited availability. Despite of all these disadvantages, MRI is increasingly being used for the pre-operative work-up of ARM patients.[15] Conventional imaging techniques such as colostography/fistulography have many disadvantages such as operator dependency, perforation, false impression of lower anomaly, troublesome, and radiation exposure.

In our study, we have evaluated 30 patients with anorectal malformation using MRI and conventional imaging techniques (colostography/fistulography) and these results were compared using surgery as the reference standard.

MATERIALS AND METHODS

All the patients were examined using 3-Tesla MR system (siemens, magnetomskyra), after taking consent from their parents as all the patients are children and infants. Scanning was done under sedation using midazoloam or ketamin as anesthetic agent. Body coil or head coil (infants) was used. Images of the pelvis to assess the level and type of ARM as well as the bulk of the sphincter muscle complex were acquired in the axial, coronal, and sagittal plane using T1 and T2-weighted Turbo Spin-Echo (T2W TSE) sequences (repetition time ms/echo time ms - 5000/132; field of view-130–150; section thickness-1.5 mm; gap-1 mm; number of signals acquired-2; flip angle-90; matrix-512 X 512; acquisition time). In the coronal and axial section, orientation was parallel and perpendicular to the plane of the anal canal, respectively. STIR images were also taken in three orthogonal planes whichever required. Total scanning time was 20–25 min.

Pressure colostography was performed by inserting a Foley catheter in the distal rectal pouch and by injecting water-soluble non-ionic contrast media (Iohexol) into it and then subsequent images were taken in AP and lateral view using computed radiography system. When the neonate did not have a colostomy stoma, the distal fistula was injected with non-ionic contrast agent and images were taken in AP and lateral view.

Analysis of the MR images was based on the following criteria. The location of the transition of the normal rectal mucosa into the fistula was evaluated. Pubococcygeal line is the line extending from the lower border of the pubic symphysis to the coccyx. It corresponds with the attachment of levatorani muscle to the pelvic wall. It separates high type of ARM from other types with high-type lying above this line.[16] I-plane (Ischeal plane)passes through the lowest point of the ischial tuberosity parallel to the above line. It separates intermediate type from low type (lying above and below this line, respectively).[16] Since no pressure was applied during MRI to dilate the bowel loop, differentiation between normal colon and fistula was based on the layered pattern of the bowel segment. If the different layers of bowel wall (mucosa, submucosa. and muscle layer) were visualized, it was classified as normal bowel and if no layer was visible, it was classified as a fistula [Figures 1 and 2]. The presence of fistula and its type was based on Krickenbeck's classification. The degree of development of the puborectalis and external sphincter muscle complexis assessed in the coronal and axial planes. If RWPR <0.18 and RWEAS <0.15, it is termed as poor development of muscles.[17-19] RWPR is defined as the total width of puborectalis muscle/half distance of ischial tuberosities. Similarly, RWEAS is defined as total width of external anal sphincter/half distance of ischial tuberosity. Other associated anomalies involving the vertebrae, spinal cord, and/or the genitourinary system anomalies are evaluated. An ectopic anus is described as an anal index of <0.34 in girls and <0.46 in boys. The anal index is defined as the ratio of the scrotal – anal distance to the scrotal–coccygeal distance in males, and the ratio of the fourchette–anal distance to the fourchette–coccygeal distance in females.[20]

Krickenbeck's International Classification

Major clinical groups
Perineal fistula
Recto-urethral fistula
Bulbar
Prostatic
Recto-vesical fistula
Vestibular fistula
Cloaca
No fistula anal stenosis
Regional/rare variants-Pouch colon
Rectal atresia/stenosis
Recto-vaginal fistula
H-type fistula
Others

Interpretation of cologram findings were done on the basis of termination of the distal opacified bowel loop in reference to the pubococcygeal line and ischial-plane. The presence of some abnormal tract suggesting fistulous communication [Figure 1]. The presence of any associated anomaly in spine is also documented. Deficiency of the

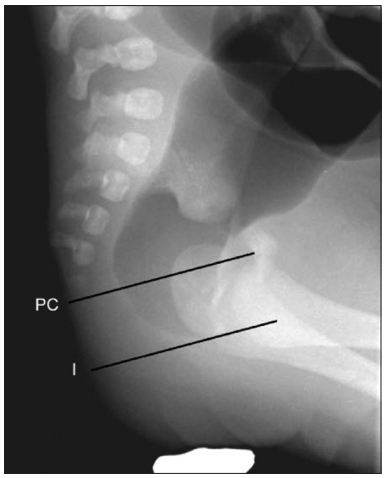

Figure 1: Prone, cross-table lateral radiograph of a pelvis demonstrating the pubococcygeal (PC) line between the pubic symphysis and coccyx, and the ischial (I) line running parallel to the PC line at the inferior aspect of the ischium. In the this example the terminal bowel gas extends to the I point in a child with a rectoprostatic urethral fistula

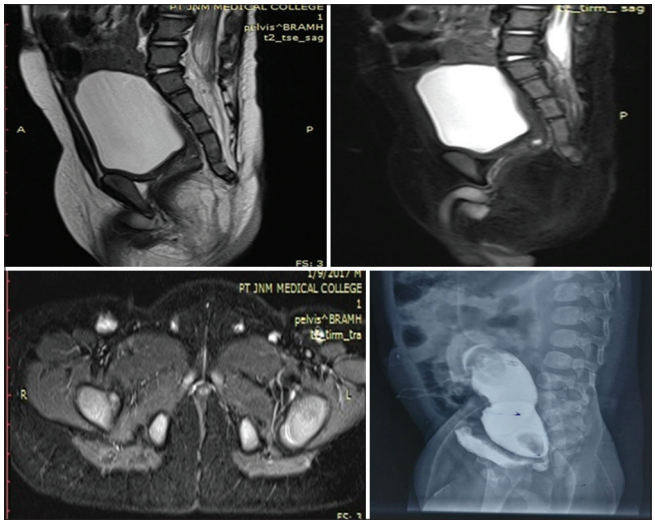

Figure 2: 8 month old male child with no external anal opening. He had undergone colostomy soon after his birth. Pressure colostography and MRI was performed[A]. (T2-weighted sagittal image)- Distal anal canal not visualized and proximal anal canal and rectum is displaced anteriorly and is terminating just below the pubo-coccygeal line communicating anteriorly with bulbar urethra. [B] STIR sagittal image- anal canal is displaced anteriorly and is communicating with bulbar urethra.[C]. (STIR Axial images)- Common channel for urethra and anal canal can be seen. [D]. (Pressure colostography – lateral images- normally opacified and dilated rectum with recto-bulbar fistula can be seen.

fourth and fifth sacral vertebrae usually allows normal innervation of the bladder and levatorani and adequate development of the levator. Deficiency of the third, fourth, and fifth sacral vertebrae is usually accompanied by variable abnormal nerve and muscle development, and most patients are incontinent. Deficiencies involving the first or second sacral segments are always associated with incontinence and poorly developed and innervated levatorani and pelvic floor musculature.[20]

RESULTS

The study included 30 patients with anorectal malformation who underwent MRI and colostography/fistulography. Age of the patients varies from 8 months to 5 years. Out of the 30 patients, 24 underwent pressure colostography and six underwent fistulography, while all patients underwent MRI examination. All patients underwent corrective surgery and the results of the MRI and colostography and fistulography were correlated with the surgical findings.

MRI was able to correctly identify type of ARM in 28 out of 30 patients (93.3%). It was able to identify all the patients with high type, 7 out of 7 (100%), 15 out of 16 patients (93.8%) with intermediate type, and 6 out of 7 patients (85.7%) with low type. However, one intermediate type was falsely identified as high type and one low type was identified as intermediate type. Colostography correctly identified the type of ARM in 28 out of 30 patients (93.3%). One high type was falsely identified as intermediate type and one low type was identified as intermediate type [Table 1].

MRI was able to correctly identify type of fistula in 27 out of 27 patients (81.48%). MRI was able to correctly identify 10 out of 12 patients (83.3%) with recto-bulbar fistula, 5 out of 7 patients (71.4%) with recto-prostatic fistula, 2 out of 2 patients (100%) with perineal fistula, 2 out of 2 patients (100%) with recto-vaginal fistula, and 3 out of 4 patients (75%) of recto-vestibular fistula. On MRI, two recto-prostatic fistula were mis-interpretated as recto-bulbar fistula, two recto-bulbar fistula were mis-interpretated as recto-prostatic fistula, and one recto-vaginal fistula was mis-interpretated as recto-vestibular fistula.

Table 1: Type of ARM on different investigations

Type of ARM	MRI		Colostography/fistulography		Surgery	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
High	8	26.7	6	20.0	7	23.3
Intermediate	16	53.3	18	60.0	16	53.3
Low	6	20.0	6	20.0	7	23.3
Total	30	100.0	30	100.0	30	100.0

MRI: Magnetic resource imaging

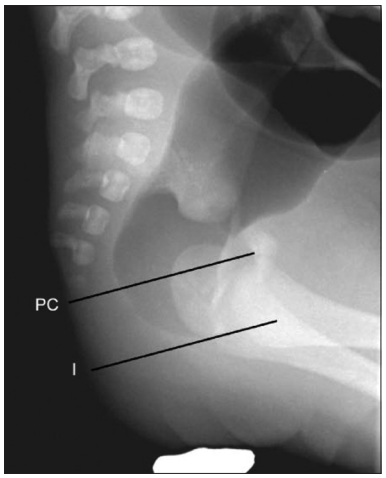

Figure 3: 2 Year old boy came with no external anal opening. He had undergone colostomy soon after birth. Pressure colostography and MRI pelvis was performed. [A]. (T2-weighted sagittal image)- Distal anal canal not visualized and proximal anal canal and rectum is displaced anteriorly and is terminating just below the pubo-coccygeal line communicating anteriorly with prostatic urethra. [B].T2 wieghted axial images- anal canal is displaced anteriorly and is lying just behind the prostatic urethra.[C]. (T2 wighted axial images)- Common channel for urethra and anal canal can be seen. [D]. (T2 wighted coronal images)- Normally developed levator ani and puborectalis muscle can be seen.

Colostography/fistulography correctly identified the presence of fistula in 10 out of 27 patients (37%). It failed to identify 16 out of 27 patients (59.25%) of surgically proven fistula. Colostography/fistulography failed to achieve significant association with surgery (*P*-value 0.197) for detection of presence of fistula [Tables 2 and 3].

It was possible to clearly visualize and evaluate the bulk of muscles the levatorani, pubo-rectalis muscle, and external sphincter in all the patients with MRI. On MRI, out of 30 patients, 18 (60%) patients were identified with normal muscle development and 12 (40%) patients with poor muscle development.

On colostography/fistulography, the development of muscles was predicted on the basis of development of sacral vertebrae. In our study, 11 patients had complete or partial absence of sacral vertebrae, out of which, eight patients had absence of three or >three vertebrae and were designated with poorly developed muscles. Twenty-two patients (73.3%) were identified with normal muscle development and 8 patients (26.7%) with poorly developed muscles. Seven patients who were identified with normal muscle development on conventional techniques (colostography/fistulography) showed poor muscle development on MRI. Three patients who were identified with normal muscle development on MRI were diagnosed as poorly developed on conventional techniques (colostography/fistulography). However, this difference was not statistically significant [Table 4].

In the present study, the incidence of associated anomalies was 43.3%. The most common associated anomaly was vertebral anomaly followed by spinal cord anomalies and genito-urinary anomalies. MRI showed genito-urinary anomaly in two out of 30 (6.67%) patients which included hydronephrosis in one patient and ambiguous genitalia in one patient, isolated vertebral anomaly in 5 out of 30 patient (26.67%), caudal regression syndrome in 2 out of 30 patients (6.67%), and vertebral agenesis with tethered cord in 1 out of 30 patients (3.33%). There was significant correlation between MRI and colostography and fistulography for detecting the vertebral anomaly.

Table 2: Presence of fistula on different investigations

Presence of fistula	Frequency	Percent	*P* value
MRI	27	90.0	<0.0001
colostography/fistulography	10	33.3	
Surgery	27	90.0	

DISCUSSION

In the present study, we compared high-resolution MRI findings with that of the colostography/fistulography, taking surgical findings as reference standard. We found that MRI is better diagnostic tool than colostography/fistulography for evaluation of anorectal malformation in

Table 3: Type of fistula on different investigations

Type of fistula	MRI		Colostography/fistulography		Surgery	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
None	3	10.0	19	63.3	3	10.0
Perineal fistula	2	6.7	2	6.7	2	6.7
Recto-bulbar	12	40.0	5	16.7	12	40.0
Recto-prostatic	7	23.3	0	0	7	23.3
Recto-vaginal	3	10.0	2	6.7	2	6.7
Recto-vestibular	3	10.0	1	3.3	4	13.3
Total	30	100.0	30	100.0	30	100.0

MRI: Magnetic resource imaging

Table 4: Comparison of muscle development as detected by MRI and conventional investigation

Muscle development on MRI	Muscle development on conventional investigation		Total
	Normal	Poor	
Normal	15	3	18
	68.2%	37.5%	60.0%
Poor	7	5	12
	31.8%	62.5%	40.0%
Total	22	8	30
	100.0%	100.0%	100.0%

MRI: Magnetic resource imaging

terms of detection of fistula, type of fistula, development of pelvic floor muscles, and presence of associated anomalies. MRI is equally sensitive to conventional techniques in determination of type of anorectal malformation.

The most common type of anorectal malformation was intermediate type followed by high type then low type. The result of this study correlated with the result of the study done by Abdulkadir *et al.*[21] and another study done by Tang *et al.*[22] The sensitivity and specificity of MRI for detection of high type of ARM were 85.6% and 100%, for intermediate type 100% and 85.7% and for low type 85.7% and 85.6%, respectively. The sensitivity and specificity of colostography/fistulography for identification of high type of ARM were 85.6% and 100%, for intermediate type – 100% and 85.7% and for low type 85.7% and 95.6%, respectively. Significant association was noted between colostography/fistulography for identification of type of ARM. Thus, it can be concluded that MRI and conventional imaging (colostography/fistulography) are nearly equal sensitive for the detection of type of ARM (high, intermediate, and low).The result of this study does not matches with a similar study done by Thomer *et al.*[23]

We found the sensitivity of MRI for detection of presence of fistula was 100%. The most common type of fistula was recto-bulbar fistula. Colostography identified presence of fistula in 37% cases. There was 56.7% increase in detection of fistulae with MRI in comparison to conventional imaging techniques (colostography/fistulography). The difference was found to be highly significant ($P < 0.0001$). This study result matches with the similar study done by Elsayed *et al.*[24] and Thomer *et al.*[23]

MRI was also able to delineate the pelvic floor muscles and helped in evaluation of their bulk, thus making it possible to predict the post-operative anal continence. On MRI, out of 30 patients, 18 patients (60%) were identified with normal muscle development and 12(40%) patients with poor muscle development. On colostography/fistulography, the development of muscles was predicted on the basis of development of sacral vertebrae. Twenty-two (73.3%) patients were identified with normal muscle development and 8 patients (26.7%) with poorly developed muscles on colostography. Seven patients who were identified with normal muscle development on conventional techniques (colostography/fistulography) showed poor muscle development on MRI. Three patients who were identified with normal muscle development on MRI were diagnosed as poorly developed on conventional techniques (colostography/fistulography). However, this difference was not statistically significant.

In the present study, the incidence of associated anomalies according to our MRI protocol and conventional techniques was 43.3%. The most common associated anomaly was vertebral anomaly followed by spinal cord anomalies and genito-urinary anomalies. MRI showed genito-urinary anomaly in 2/30 (6.67%) patients which included hydronephrosis in one patient and ambiguous genitalia in one patient, isolated vertebral anomaly in 5 out of 30 patient (26.67%), caudal regression syndrome in 2 out of 30 patients (6.67%), and vertebral agenesis with tethered cord in 1 out of 30 patients (3.33%). The results of this study do not matches with the result of a similar study done by Balanescu[25] and McHugh[26] likely because of limited sample size in the present study. The prevalence of associated anomalies was most common among high type (57.14%) followed by intermediate type and low type. The results match with the result of the study done by Elsayed *et al.* and Shrivastava *et al.*[27] Gross *et al.* stated that a posterior sagittal approach should never be attempted without a technically adequate high-pressure distal colostogram to determine the exact positions of the rectum and the fistula.[28] The local anatomy required for surgical planning is more precisely delineated with MRI in comparison to colostography/fistulography. There is no need for the use of intravenous contrast or local instillation of fluids into the orifices thus making the MRI non-invasive procedure.

MRI is suited for pre-operative assessment of anorectal malformation because of its excellent intrinsic contrast resolution, multi-planar imaging capabilities, and lack of ionizing radiation. Disadvantages of MRI include the need for sedation, high cost, limited availability, and relative lack of expertise. Since MRI examination is static (non-operator dependent) and images can always be re-evaluated and discussed with different physicians, MRI can produce more consistent results. Conventional imaging techniques such as colostography/fistulography have many disadvantages such as operator dependence, perforation, false impression of lower anomaly, troublesome, and radiation exposure. MRI also demonstrated other associated anomalies which are common cause of morbidity in patients with anorectal malformation.

CONCLUSION

MRI is a non-invasive and non-hazardous modality for the pre-operative work-up of anorectal malformation. Since an MRI examination is static (non-operator dependent), images can always be re-evaluated and discussed with different physicians. MRI can produce more consistent results. In the present study, MRI proved to be a better imaging technique than conventional imaging techniques (colostography/fistulography) for the detection of fistula and determination of type of fistula. It is equally sensitive to conventional techniques for detection of type of ARM. Bulk of the pelvic floor muscles can be evaluated with MRI and thus the post-operative anal continence can be predicted, which is not possible by conventional imaging techniques (colostography/fistulography) where we predict the anal continence on the basis of presence or absence of sacral vertebrae. Other anomalies which are common cause of morbidity in patients of ARM can be easily evaluated on MRI. Thus, MRI is a better imaging technique than conventional imaging techniques (colostography/fistulography) for complete pre-operative workup of anorectal malformation.

REFERENCES

1. Cuschieri A, EUROCAT Working Group. Descriptive epidemiology of isolated anal anomalies: A survey of 4.6 million births in Europe. Am J Med Genet 2001;103:207-15.
2. Boocock GR, Donnai D. Anorectal malformation: Familial aspects and associated anomalies. Arch Dis Child 1987;62:576-9.
3. Kluth D, Hillen M, Lambrecht W. The principles of normal and abnormal hindgut development. J Pediatr Surg 1995;30:1143-7.
4. N'Guessan G, Stephens FD. Covered anus with anocutaneous fistula: The muscular sphincters. J Pediatr Surg 1986;21:33-5.
5. Cho S, Moore SP, Fangman T. One hundred three consecutive patients with anorectal malformations and their associated anomalies. Arch Pediatr Adolesc Med 2001;155:587-91.
6. Smith ED. Incidence, frequency of types, and etiology of anorectal malformations. Birth Defects Orig Artic Ser 1988;24:231–246
7. Cuschieri A. Anorectal anomalies associated with or as part of other anomalies. Am J Med Genet 2002;110:122-30.
8. Bradham RR. Imperforate anus; report of 130 cases. Surgery 1958;44:578-84.
9. Endo M, Hayashi A, Ishihara M, Maie M, Nagasaki A, Nishi T, Saeki M. Analysis of 1,992 patients with anorectal malformations over the past two decades in Japan. Steering Committee of Japanese Study Group of Anorectal Anomalies. J Pediatr Surg 1999;34:435-41.
10. Ratan SK, Rattan KN, Pandey RM, Mittal A, Magu S, Sodhi PK. Associated congenital anomalies in patients with anorectal malformations-a need for developing a uniform practical approach. J Pediatr Surg 2004;39:1706-11.
11. Alamo L, Meyrat BJ, Meuwly JY, Meuli RA, Gudinchet F. Anorectal malformations: Finding the pathway out of the labyrinth. Radiographics 2013;33:491-512.
12. Holschneider A, Hutson J, Pena A, Beket E, Chatterjee S, Coran A, et al. Preliminary report on the international conference for the development of standards for the treatment of anorectal malformations. J Pediatr Surg 2005;40:1521-6.
13. Pena A. Posterior sagittal approach for the correction of anorectal malformations. Adv Surg 1986;19:69-100.
14. Thomeer MG, Devos A, Lequin M, De Graaf N, Meeussen CJ, Meradji M, et al. High resolution MRI for preoperative work-up of neonates with an anorectal malformation: A direct comparison with distal pressure colostography/fistulography. Eur Radiol 2015;25:3472-9.
15. Podberesky DJ, Towbin AJ, Eltomey MA, Levitt MA. Magnetic resonance imaging of anorectal malformations. Magn Reson Imaging Clin N Am 2013;21:791-812.
16. Holschneider A, Hutson J, Pena A, Beket E, Chatterjee S, Coran A, et al. Preliminary report on the international conference for the development of standards for the treatment of anorectal malformations. J Pediatr Surg 2005;40:1521-6.
17. Nievelstein RA, Vos A, Valk J. MR imaging of anorectal malformations and associated anomalies. Eur Radiol 1998;8:573-81.
18. Levitt MA, Pena A. Outcomes from the correction of anorectal malformations. Curr Opin Pediatr 2005;17:394-401.
19. de Medina VH, Mellstam L, Amark P, Frenckner B. Neurovesical dysfunction in children after surgery for high or intermediate anorectal malformations. Acta Paediatr 2004;93:43-6.
20. Holschneider AM, Hutson JM. Holschneider's Anorectal Malformation in Children. Berlin Heidelberg: Springer-Verlag; 2006. p. 178.
21. Jones FW. The nature of malformations of the rectum and the urogenital passages. Br Med J 1904;2:1630-4.
22. Fritsch H, Brenner E, Lienemann A, Ludwikowski B. Anal sphincter complex. Reinterpreted morphology and its clinical relevance. Dis Colon Rectum 2002;45:188-94.
23. Holschneider AM, Hutson JM. Holschnieder Anorectal Malformation. Berlin Heidelberg: Springer-Verlag; 2012. p. 195.
24. Fritsch H, Lienemann A, Brenner E, Ludwikowski B. Clinical anatomy of the pelvic floor. Adv Anat Embryol Cell Biol 2004;175:1-64.
25. Aigner F, Zbar AP, Ludwikowski B, Kreczy A, Kovacs P, Fritsch H. The rectogenital septum: Morphology, function, and clinical relevance. Dis Colon Rectum 2004;47:131-40.
26. Ludwikowski B, Oesch-Hayward I, Fritsch H. Rectovaginal fascia: An important structure in pelvic visceral surgery? About its development, structure, and function. J Pediatr Surg 2002;37:634-8.
27. Amussat JJ. Observation sur une operation d'anus artifical pratiquee avec success par un nouveau procede. Gaz Med Paris 1835;3:753-8.
28. Stephens FD, Smith ED. Anorectal Malformation in Children. Chicago: Year Book Medical Publications; 1971.
29. Ladd WE, Gross RE. Congenital malformations of rectum and anus: Report of 162 cases. Am J Surg 1964;23:167-83.
30. Wangensteen OH, Rice CO. Imperforate anus. A method of determining the surgical approach. Ann Surg 1930;92:77-81.
31. Santulli TV, Schullinger JN, Amoury RA. Malformations of the anus and rectum. Surg Clin North Am 1964;45:1253-71.
32. Nixon H, O'Donnell B. The Essentials of Paediatric Surgery. 3rd ed. London: William Heinemann, Medical Books Ltd.; 1976. p. 28-36
33. Peña A. Imperforate anus and cloacal anomalies. In: Ashcraft MD, editor. Pediatric Surgery. 3rd ed. London: WB Saunders; 2000. p. 473-92.
34. Louw JH. Congenital abnormalities of rectum and anus. Curr Probl Surg 1965;31:1-64.
35. Endo M, Hayashi A, Ishihara M, Maie M, Nagasaki A, Nishi T, et al. Analysis of 1,992 patients with anorectal malformations over the past two decades in Japan. Steering Committee of Japanese Study Group of Anorectal Anomalies. J Pediatr Surg 1999;34:435-41.
36. Nazer J, Hubner ME, Valenzuela P, Cifuentes L. Anorectal congenital malformations and their preferential associations. Experience of the Clinical Hospital of the University of Chile. Period 1979-1999. Rev Med Chil 2000;128:519-25.
37. Endo M, Hayashi A, Ishihara M, Maie M, Nagasaki A, Nishi T, et al. Analysis of 1,992 patients with anorectal malformations over the past two decades in Japan. Steering Committee of Japanese Study Group of Anorectal Anomalies. J Pediatr Surg 1999;34:435-41.
38. Belman AB, King LR. Urinary tract abnormalities associated with imperforate anus. J Urol 1972;108:823-4.
39. Hoekstra WJ, Scholtmeijer RJ, Molenaar JC, Schreeve RH, Schroeder FH. Urogenital tract abnormalities associated with congenital anorectal anomalies. J Urol 1983;130:962-3.
40. Munn R, Schillinger JF. Urologic abnormalities found with imperforate anus. Urology 1983;21:260-4.
41. Parrott TS. Urologic implications of anorectal malformations. Urol Clin North Am 1985;12:13-21.

42. Fleming SE, Hall R, Gysler M, McLorie GA. Imperforate anus in females: Frequency of genital tract involvement, incidence of associated anomalies, and functional outcome. J Pediatr Surg 1986;21:146-50.
43. Botto LD, Khoury MJ, Mastroiacovo P, Castilla EE, Moore CA, Skjaerven R, et al. The spectrum of congenital anomalies of the VATER association: An international study. Am J Med Genet 1997;71:8-15.
44. Quan L, Smith DW. The VATER association. Vertebral defects, anal atresia, T-E fistula with esophageal atresia, radial and renal dysplasia: A spectrum of associated defects. J Pediatr 1973;82:104-7.
45. Kaufman RL. Birth defects and oral contraceptives. Lancet 1973;1:1396.
46. Nora AH, Nora JJ. A syndrome of multiple congenital anomalies associated with teratogenic exposure. Arch Environ Health 1975;30:17-21.
47. Martinez-Frias ML, Bermejo E, Frias JL. The VACTERL association: Lessons from the Sonic hedgehog pathway. Clin Genet 2001;60:397-8.
48. McMullen KP, Karnes PS, Moir CR, Michels VV. Familial recurrence of tracheoesophageal fistula and associated malformations. Am J Med Genet 1996;63:525-8.
49. Nezarati MM, McLeod DR. VACTERL manifestations in two generations of a family. Am J Med Genet 1993;82:40-2.
50. Smith ED, Saeki M. Associated anomalies. Birth Defects Orig Artic Ser 1988;24:501-49.
51. Smith ED, Saeki M. Associated anomalies. Birth Defects Orig Artic Ser 1988;24:501-49.
52. Mahajan JK, Kumar D, Chowdhary SK, Rao KL. Anorectal malformation with malrotation of gut. Eur J Pediatr Surg 2003;13:63-5.
53. Haynes JH, Bagwell CE. Hirschprung's disease and imperforate anus in Pallister-Hall syndrome: A new association. J Pediatr Surg 2003;38:1411-2.
54. Baltogiannis N, Mavridis G, Soutis M, Keramidas D. Currarino triad associated with Hirschsprung's disease. J Pediatr Surg 2003;38:1086-9.
55. Hartman EE, Oort FJ, Aronson DC, Hanneman MJ, van der Zee DC, Rieu PN, et al. Critical factors affecting quality of life of adult patients with anorectal malformations or Hirschsprung's disease. Am J Gastroenterol 2004;99:907-13.
56. Shanske A, Ferreira JC, Leonard JC, Fuller P, Marion RW. Hirschsprung disease in an infant with a contiguous gene syndrome of chromosome 13. Am J Med Genet 2001;102:231-6.
57. Wang J, Shi C, Yu S, Wu Y, Xu C. A rare association of rectal and genitourinary duplication and anorectal malformation. Chin Med J (Engl) 2003;116:1955-7.
58. Smith ED, Saeki M. Associated anomalies. Birth Defects Orig Artic Ser 1988;24:501-49.
59. Qi BQ, Beasley SW, Frizelle FA. Evidence that the notochord may be pivotal in the development of sacral and anorectal malformations. J Pediatr Surg 2003;38:1310-6.
60. Narasimharao KL, Prasad GR, Katariya S, Yadav K, Mitra SK, Pathak IC. Prone cross-table lateral view: An alternative to the invertogram in imperforate anus. AJR Am J Roentgenol 1983;140:227-9.
61. Cremin BJ, Cywes S, Louw JH. A rational radiological approach to the surgical correction of anorectal anomalies. Surgery 1972;71:801-6.
62. Lernau OZ, Jancu J, Nissan S. Demonstration of rectourinary fistulas by pressure gastrografin enema. J Pediatr Surg 1978;13:497-8.
63. Han TI, Kim IO, Kim WS. Imperforate anus: US determination of the type with infracoccygeal approach. Radiology 2003;228:226-9.
64. Ikawa H, Yokoyama J, Sanbonmatsu T, Hagane K, Endo M, Katsumata K, et al. The use of computerized tomography to evaluate anorectal anomalies. J Pediatr Surg 1985;20:640-4.
65. Kohda E, Fujioka M, Ikawa H, Yokoyama J. Congenital anorectal anomaly: CT evaluation. Radiology 1985;157:349-52.
66. McHugh K, Dudley NE, Tam P. Pre-operative MRI of anorectal anomalies in the newborn period. Pediatr Radiol 1995;25 Suppl 1:S33-6.
67. AA Shah, Kothari MR, Bhattacharjee N, Shah AJ, Shah AV. Magnetic resonance imaging in anorectal malformation. J Indian Assoc Pediatric Surg 2001;6:4-13.
68. Tang ST, Wang Y, Mao YZ, Tong QS, Li SW, Cao ZQ, et al. MRI of anorectal malformations and relationship of the developmental state of the sphincter muscle complex with fecal continence. World J Pediatr 2006;3:223-30.
69. Boemers TM, Ludwikowski B, Forstner R, Schimke C, Ardelean MA. Dynamic magnetic resonance imaging of the pelvic floor in children and adolescents with vesical and anorectal malformations. J Pediatr Surg 2006;41:1267-71.
70. Abdulkadir AY, Abdur-Rahman LO, Adesiyun OM. Nonfluoroscopic pressure colostohraphy in the evaluation of genitourinary fistula of anorectal malformation: Experience in a resource-poor environment. Pediatr Radiol 2009;39:132-6.
71. Mohammada SA, AbouZeid AA. MRI of persistent cloaca: Can it substitute conventional imaging? Eur J Radiol 2012;82:241-51.
72. Podberesky DJ, Towbin AJ, Eltomey MA, Levitt MA. Magnetic resonance imaging of anorectal malformations. Magn Reson Imaging Clin N Am 2013;21:791-812.
73. Yang F, Sheng M, Wang J, Guo W, Wang Q, Han X.Clinical application of magnetic resonance imaging in congenital anorectal malformation. Zhonghua Er Ke Za Zhi 2014;52:41-5.
74. Thommer MG, Devos A, Lequin M, De Graff N, Meeussen CJ, Meradji M, et al. High resolution MRI for preoperative work-up of neonates with an anorectal malformation: A direct comparison with distal pressure colostography/fistulography. Eur Radiol 2015;25:3472-9.
75. Elsayed RF, Kamal HA, El-Liethy NE. Recent advances in MRI in the preoperative assessment of anorectal malformations. Egypt J Radiol Nucl Med 2016;47:711-2.
76. Sachs TM, Applebaum H, Touran T, Taber P, Darakjian A, Colleti P. Use of MRI in evaluation of anorectal anomalies. J Pediatric Surg 1990;25:817-21.
77. McHugh K. The role of radiology in children with anorectal anomalies; with particular emphasis on MRI. Eur J Radiol 1998;26:194-9.
78. Balanescu RN, Topor L, Moga A. Anomalies associated with anorectal malformation. Chirurgia (Bucur) 2013;108:38-42.
79. Nah SA, Ong CC, Lakshmi NK, Yap TL, Jacobsen AS, Yee Low. Anomalies associated with anorectal malformations according to the Krickenbeck anatomic classification. J Pediatric Surg 2012;47:2273-8.
80. Shrivastava V, Ray AK, Patra R, Basu KS, Samanta N, Saha K. Urogenital anomalies associated with anorectal malformation. 2005;10:44-7.

How to cite this article: Kapoor MR. MRI in Contrary to Conventional Imaging Techniques in Evaluation of Anorectal Malformation. Int J Sci Stud 2023;10(10):19-25.

Source of Support: Nil, **Conflicts of Interest:** None declared.