Narrative Review
Acta Medica Academica 2022;51(3):243-248
DOI: 10.5644/ama2006-124.394

Anatomical Variations of Vascular Anatomy in Meckel's Diverticulum

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Received: 14 October 2022; **Accepted:** 30 December 2022

Abstract

Objective. The objective of the current study was to describe the anatomical variations of vessels observed in patients with Meckel's Diverticulum. **Methods.** A narrative review of the literature was undertaken by means of the PubMed database, using the terms: "Meckel's Diverticulum AND vessels", "Meckel's Diverticulum AND anatomical variation" and "Meckel's Diverticulum variation". Classical anatomical textbooks were also used for normal anatomy. Additional articles provided useful information in relation to the aim of this review. Hence, the articles that met the inclusion criteria were included in this review, and the collected data were categorized into a single table. **Results.** The majority of studies indicated the presence of an abnormal vitelline artery. Other angiographic findings concerned variations of the ileal and the iliac arteries. However, the literature revealed the presence of vascular variations without the existence of Meckel's Diverticulum, whereas a remnant of the vitelline vein may be present, but it is very rare. **Conclusion.** The detection of vascular variations accompanying Meckel's Diverticulum is not always easy and requires the correct choice of imaging method to prevent misdiagnosis.

Key Word: Meckel's Diverticulum ▪ Anatomical Variation ▪ Vascular Variation ▪ Vitelline Artery ▪ Vitelline Vein.

Introduction

Meckel's Diverticulum (MD) was described for the first time in 1589 by Fabricius Hildanus and is thought to be the most frequent congenital gastrointestinal malformation (1-4). It is caused by the persistence of the omphalomesenteric duct, and it is a true diverticulum as it contains all the three layers of the intestinal wall: the mucosa, muscularis propria and adventitia (5). A mnemonic technique is used since MD is considered to follow "the rule of twos": it is present in about 2% of the general population, more frequent in males with a predominance 2:1, it appears in the first two years of life, it contains two types of mucosal, it is symptomatic in 2% of the affected population, its length is two inches (5 cm), and it is found two feet away from the ileocecal valve (1). The diagnosis is often made incidentally in patients undergoing abdominal exploration surgery, most commonly for acute appendicitis, or on postmortem dissection for forensic medicine cases (5). MD can be asymptomatic, but it may also appear with complications such as: hemorrhage, inflammation, obstruction, ulceration, perforation, intussusception, volvulus, and neoplasms (5-7). The vascular variations that may accompany MD can be found during imaging, such as angiography.

The aim of this study was to review the anatomical variations of the vessels in patients with MD.

Methods

An advanced executive literature search was conducted in PubMed, Google Scholar and other available scientific websites and medical journals, using the following terms: "Meckel's Diverticulum AND vessels", "Meckel's Diverticulum AND anatomical variation" and "Meckel's Diverticulum variation". The resulting literature was carefully screened by

a single investigator. Only studies in English and referring to humans were included. No additional search filters, such as text availability, article type and publication date, were applied. Using the snowballing technique, further references taken from the initial articles with useful information relating to the aim of the review were also screened and taken into consideration. The extracted data were classified in a table according to the type of vascular variation and the presence of MD.

Results

The search of the literature retrieved articles with useful information that are described in Table 1. Most studies suggested the presence of the vitelline artery. Pandey et al. in their study presented a case report of a young male diagnosed with MD accompanied by a blood vessel touching the intestine within the mesodiverticulum band, which was suggested to be a remnant of the vitelline artery (2). Along the same lines, Okazaki et al. reported a young male with a bleeding MD accompanied by a vitelline artery (8). Moreover, Miyoshi et al. also claimed that they noticed the presence of a right vitelline artery (9). Okazaki et al. observed in five patients with MD that the vitelline artery appeared, derived from the distal ileal artery, with increased length and no branches (5). The study by Mitchell

Table 1. Eligible Studies That Correlate Meckel Diverticulum with Vascular Anatomical Variations

Researchers	Year	Type of study	Gender of patients	Variation	Presence of MD	N (%)
Pandey et al. (2)	2016	CR*	Male	Remnant of the vitelline artery	Yes	1
Okazaki et al. (8)	1992	CR*	Male	Remnant of the vitelline artery	Yes	1
Miyoshi et al. (9)	1984	CR*	Male	Remnant of the right vitelline artery	Yes	1
Okazaki et al. (5)	1993	RS† 5 patients	4 males 1 female	Remnant of the vitelline artery: enlogated without branches	Yes	5 (100)
				Irregular tortuous vessels		5 (100)
				Capillary straining		2/5 (40)
Mitchell et al. (10)	1997	RS† 16 patients' angiograms	13 males 3 females	Remnant of the vitelline artery	Yes	11/16 (69)
				The vitellointestinal artery not depicted		5/16 (25)
				Vascular blush		4/16 (25)
				Early venous return		4/16 (25)
				Arterial deformities		2/16 (12.5)
				Vitellointestinal artery without MD	No	4/16 (25)
Takeda et al. (11)	1977	CR*	Female	Abnormal ileal artery	Yes	1
Hall TJ (12)	1975	CR*	Male	Abnormal artery from the superior mesenteric artery	Yes	1
Geelhoed et al. (13)	1986	CR*	Male	Enlargement and elongation of the right iliac artery	Yes	1
Kitsuki et al. (4)	1992	CR*	Female	Enlargement and elongation of the embryonic artery	Yes	1
Sakai et al. (14)	2006	CR*	Male	Abnormal vitello-intestinal artery aneurysm	Yes	1
Watanabe et al. (15)	2011	CR*	Male	Preduodenal portal vein	Yes	1
Mwila et al. (17)	2022	CR*	Female	Remnant of the vitelline artery	No	1
Date et al. (18)	2018	CR*	Male	Remnant of the vitelline artery	No	1
Jalil et al. (19)	2012	CR*	Male	Remnant of the vitelline artery	No	1
Sprangenberg (20)	1819	CR*	NA‡	Remnant of the vitelline vein	NA‡	1
Buchnan et al. (21)	1940	CR*	Male	Remnant of the vitelline vein	NA‡	1
Kleinhaus et al. (22)	1974	CR*	Male	Remnant of the vitelline vein	NA‡	1

* Case report; † Retrospective study; ‡ Not applicable.

et al. (10) is of great interest. The researchers studied the angiograms of 16 patients who had undergone resection of MD, and they observed that 11 patients (69%) had a persistent vitellointestinal artery, nine of them with MD. In these patients the ileal arteries had branches. Other abnormal angiography findings included vascular blush, early venous return, and arterial deformities.

In addition, an abnormal ileal artery was found in a case of a bleeding MD, and in another case an abnormal artery, derived from the superior mesenteric arterial trunk, confirmed the diagnosis of MD (11, 12). Geelhoed et al. concluded with a diagnosis of MD after angiography showed an enlargement and elongation of the right iliac artery, at various points in the abdomen and erythematous mucosa (13). This patient had no sites of bleeding. Another case referred to a pregnant woman who had undergone surgery for resection of symptomatic MD, and the preoperative imaging revealed an artery, increased in length and width, with no branches, that is the embryonic artery (4). It is worth noting a case report referring to the case of an abnormal vitello-intestinal artery aneurysm in an asymptomatic case of MD (14). Last but not least, Watanabe et al. described a clinical case of MD accompanied by a preduodenal portal vein (PDPV) (15). The PDPV is an embryonic variation that is the result of the remnant of the ventral and caudal anastomosis of the vitelline veins (15). The majority of these cases are recorded in children, and the patients are either asymptomatic or present with high bowel obstruction (15).

However, some researchers have recorded the presence of a residual of the vitelline artery without MD (16). Mwila et al. described a case report of a 40-year-old woman with the remnants of a vitelline artery which led to obstruction of the small intestine (17). The patient presented with a fibrous ileal-mesenteric band not attached to MD. Along the same lines, Date et al. and Jalil et al. recorded a remnant of the vitelline artery without MD, where the former noticed simultaneous appendicitis (18, 19). The remnant of the vitelline vein is infrequent and, according to Miyoshi et al., that variation has been described in only three cases in the literature (9, 20-22).

Discussion

The MD is thought to be formed from a residue of the proximal portion of the yolk stalk. It is formed when the omphalomesenteric duct, which connects the midgut with the yolk stalk, does not turn back in the seventh week of pregnancy, as by that time the omphalomesenteric duct, the yolk sac and the vitelline arteries have involuted (1). The persistence of that connection leads to the formation of MD (6). In other words, the origin of MDs is considered to be failure of obliteration of the proximal portion of the vitelline duct (23, 24). Its inflammation can be misdiagnosed as appendicitis because it is close to the appendix in location (25). The remnants of the vitelline duct are depicted in Figure 1.

In terms of embryology, MD consists of three anatomical parts: the omphalomesenteric duct, two vitelline arteries and one vitelline vein (2, 17, 18). The left vitelline artery degenerates, whereas the right remains as the superior mesenteric artery, and is the main blood supply for the MD (2). Nevertheless, the left vitelline artery may persist. Rutherford referred to three types of remnants of vitelline arteries: the right vitelline artery as the

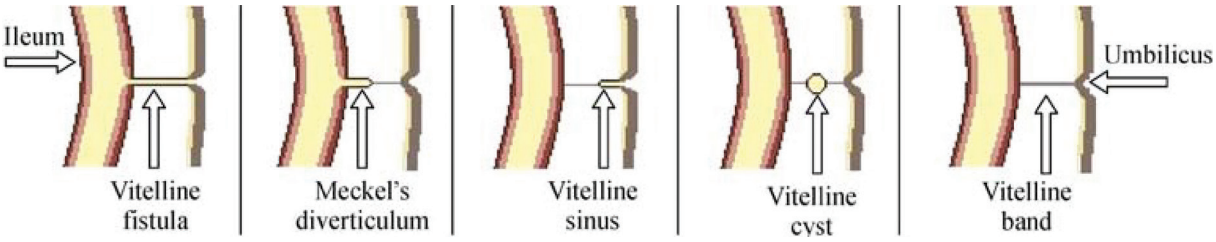

Figure 1. Diagrams showing vitelline duct remnants (24).

terminal part of the superior mesenteric artery, the second type which originates near the ileocecal artery as a branch from the superior mesenteric artery, and the third, which includes the left vitelline artery that arises from the aorta (26). The remnant of the vitelline vein is extremely rare, and derives from the back wall of the umbilicus (9). Variations of the vitelline circulation are not usual, and they are estimated to appear in 8-15% of patients with MD. Their identification is crucial for the diagnosis of MD and they are associated with increased probability of a bleeding MD (2, 4, 5). It should also be underlined that vascular variations may occur without the presence of MD (2, 19). Vascular remnants present as fibrous bands covering the peritoneum, and they expand from the ileal branch of the superior mesenteric artery to the MD, or to the umbilicus (2, 19). When there is no MD, discrimination between the remnant of the omphalomesenteric duct and the vascular remnant is not always easy. A vascular remnant is suspected when the band expands from the intestine to the mesenteric. Its recognition is of paramount importance as it can prevent hemorrhage after surgery. Researchers have emphasized that such bands should be considered to be vascular remnants until proven otherwise (19). According to Okazaki et al., the features of vitelline arteries include their increased length, the absence of branches to the ileal artery from which they are derived, and enlarged tortuous vessels (5).

The mucosae of MD is mainly ileal. It should be mentioned that ectopic mucosa can usually be recorded on histological examination, and gastric mucosa is the most common (2, 6, 19). Other less common types of mucosa include pancreatic and duodenal. Heterotopic mucosa is associated with the presence of symptoms, so it has clinical significance: for instance, acid from the gastric mucosa cells can result in ileal ulceration, hemorrhage and inflammation (2, 18). Furthermore, malignant neoplasms have been recorded that derive from the remnant omphalomesenteric duct (18). For instance, Martre et al. presented a case report of a gastrointestinal stromal tumor (GIST) on MD (3). Moreover, hemorrhage is the most frequent complication, especially in children, and in adults it can lead to chronic anemia due to the chronic blood loss from the gastrointestinal trunk (10, 12, 14).

The omphalomesenteric artery supplies the MD and is represented on angiography as a lone branch of the superior mesenteric artery (15). It should be underlined that arteriography is helpful for the diagnosis of bleeding MD and, more specifically, superselective vitelline arteriography enables the depiction of the vitelline artery (5, 10, 13, 27). When hemorrhage is taking place, arteriography is the best imaging choice. MD can be distinguished by extravasation of contrast medium (5). When bleeding stops, the diagnosis of MD can be made by observation of abnormal vessels, high density due to the heterotopic gastric mucosa, or the mesodiverticular band artery (11). It should not be forgotten that the inability to illustrate the vitelline artery does not exclude the diagnosis of MD (10). Furthermore, Oglevie et al. emphasized the importance of taking findings from other imaging methods into account, for instance, endoscopy and barium series, in order to minimize the possibility of a wrong diagnosis (28).

Limitations of the Study

Concerning the limitations of our study, it should be mentioned that most of the research that exists relies on case reports/small case series. Finally, it is equally important to highlight that aneurysms and vascular anomalies in general, even though they are not common in the general population, are of high clinical significance. A potential rupture of an aneurysm can be life-threatening, and the mortality rate is estimated to be 8.5% (14). The management of patients with a vitelline artery aneurysm and asymptomatic MD can be treated by a minimally invasive surgical procedure, if complications occur (14).

Conclusion

Meckel's diverticulum is present in 2% of the general population, and the remnants of vitelline vessels are even more infrequent. It should be noted

that the correct diagnosis of vitelline vascular remnants is challenging, especially when comorbidities such as appendicitis are present. Fortunately, there are many imaging procedures in the diagnostic armamentarium, and the careful examination and interpretation of the findings can usually lead to a diagnosis, with high accuracy. Taking all the above into consideration, it is obvious that surgeons should be aware of the existence of anatomical vascular variations and suspect them in patients with atypical abdominal symptoms, in order not to miss the diagnosis.

What Is Already Known on This Topic:

Meckel's Diverticulum (MD), even though it is present in only 2% of the general public, is still one of the most common congenital anatomical variations, but the vascular anatomical variations that may accompany it are even more rare. The clinical picture may be confusing, leading to misdiagnosis or failure to recognize the anatomical variations. There are a variety of imaging methods that can be helpful for accurate diagnosis. However, it should be underlined that surgeons should be aware of the probability of the presence of such variations, especially in patients with atypical symptoms. In this way the serious complications of such vascular variations can be prevented, thereby saving patients' lives.

What This Study Adds:

This review sums up the current literature, confirming that recognition of the anatomical vascular variations that in some cases accompany MD, is of high importance. This is because correct and early diagnosis can lead to the appropriate treatment, preventing potentially life-threatening complications.

Conflict of Interest: The authors declare that they have no conflict of interest.

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