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Review

The Venous Trunk of Henle (Gastrocolic Trunk): A Systematic Review and Meta-Analysis of Its Prevalence, Dimensions, and Tributary Variations

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Surgeons have recognized the clinical significance of the venous trunk of Henle during multiple pancreatic, colorectal, and hepatobiliary procedures. To date, no study has followed the principles of evidence-based anatomy to characterize it. Our aim was to find, gather, and systematize available anatomical data concerning this structure. The MEDLINE/PubMed, ScienceDirect, EMBASE, BIOSIS, SciELO, and Web of Science databases were searched. The following data were extracted: prevalence of the trunk of Henle, its mean diameter and length, the organization of its tributaries, method of anatomical assessment (cadaveric, radiological, or intraoperative), geographical origin, study sample, and known health status. Our search identified 38 records that included data from 2,686 subjects. Overall, the prevalence of the trunk of Henle was 86.9% (95% CI, 0.81–0.92) and the mean diameter was 4.2 mm. Only one study reported the length of the trunk (10.7 mm). The most common type of venous trunk (56.1%) was a vessel comprising three tributaries: gastric (right gastro-epiploic vein), pancreatic (most commonly the anterior superior pancreaticoduodenal vein), and colic (most commonly the superior right colic vein). The trunk of Henle is a common variant in the anatomy of the portal circulation. It is a highly variable vessel, but the most common type is a gastro-pancreato-colic trunk. In surgical practice, the presence of this venous trunk poses a high risk for bleeding, but it can also be a useful landmark during various abdominal procedures. Clin. Anat. 9999:1–13, 2018.

Key words: anatomy; meta-analysis; evidence-based medicine; venous trunk; right gastroepiploic vein; right colic vein; pancreaticoduodenectomy; colorectal surgery

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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INTRODUCTION

The venous trunk of Henle (or gastrocolic trunk) was first described by Jacob Henle in 1868 as a blood vessel (*vena gastro-colica*) that runs anteriorly to the surface of the pancreatic head. It drains into the right aspect of the superior mesenteric vein (SMV) on its concave border at an average of 2 cm from the confluence of the SMV and the splenic vein. According to the original definition, it comprises two tributaries: gastric (right gastroepiploic vein [RGEV]) and colic (right colic vein [RCV]) (Henle, 1868). Later, a third pancreatic tributary was identified, described as either the anterior superior pancreaticoduodenal vein (ASPDV) or the anterior inferior pancreaticoduodenal vein (AIPDV). Additional studies provided insights into multiple anatomical variations of these veins and their tributaries, in addition to their possible confluences (Reichardt and Cameron, 1980; Voiglio et al., 1998).

The trunk of Henle is located in the junction between the omentum, the small bowel mesentery, and the transverse mesocolon. A lack of precise anatomical knowledge during abdominal surgery can result in tearing of these fragile veins because of excessive tension, which causes massive bleeding (Kimura, 2000; Okino et al., 2001). Surgeons have recognized the clinical significance of this trunk in various hepatobiliary and colorectal procedures. Frequently, pancreaticoduodenectomy or complete mesocolic excision operations are associated with complications caused by injuring the trunk of Henle and its tributaries during mobilization of the transverse mesocolon from the anterior surface of the head of the pancreas (Kapoor, 2016). However, the venous trunk can serve as a landmark for lymph node dissection during gastrectomy or right-sided colon cancer resection (according to complete mesocolic excision principles), especially when a laparoscopic-assisted approach is used (Tajima et al., 2011). Because it is a highly variable anatomical structure, the trunk is particularly prone to accidental injury.

The aim of the recently proposed concept of evidence-based anatomy (EBA) is to apply principles of evidence-based medicine to anatomical sciences. It focuses on using systematic reviews with meta-analyses to generate weighted pooled results based on multiple morphometric and epidemiological studies of anatomical structures (Yammine, 2014; Tomaszewski et al., 2017). The morphological features of the trunk of Henle remain controversial, and the anatomy of this vein has not been studied in accordance with EBA principles. Our aim is therefore to find, gather, and systematize available anatomical data concerning the venous trunk of Henle, including its prevalence, diameter, length, and tributaries. We also intend to describe its surgical significance.

MATERIALS AND METHODS

In accordance with the World Medical Association's Declaration of Helsinki of 2013, the research was registered at http://www.researchregistry.com. The assigned unique identifying number was "reviewregistry491." Ethical approval and patient consent were not required for a systematic review using meta-analysis.

Search strategy

This study complied with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Supporting Information Supplement 1) (Moher et al., 2009). Our strategy was to find anatomical data relevant to the venous trunk of Henle. A wide search using the MEDLINE/PubMed, ScienceDirect, EMBASE, BIOSIS, SciELO, and Web of Science databases was performed up to 15th March 2018 (Supporting Information Supplement 2). We included no date or language filters. The following terms were combined using the Boolean operators "AND" and "OR" and used to search the following keywords: "gastrocolic trunk," "trunk of Henle," "gastrocolic vein," "truncus gastrocolicus," "Henle's gastrocolic trunk," "Henle gastrocolic trunk," "gastrocolic trunk of Henle," "gastrocolic veins," "trunchiul gastrocolic," "gastro-colic trunk," "gastro-colic venous trunk," "gastrocolic venous trunk." We also performed an extensive reference search in the acquired articles to identify additional relevant publications.

Eligibility assessment

Three independent reviewers performed an eligibility assessment for the full-text articles identified during the search process. At least two authors assessed each article. We included cadaveric, imaging, and intraoperative studies that reported on prevalence and/or relevant anatomical data concerning the venous trunk of Henle. The trunk of Henle was defined as a reported confluence of the RGEV with any colic or pancreatic tributary. We excluded conference papers, reviews, video articles, case reports, and studies without relevant anatomical data (i.e., data that did not concern the venous trunk of Henle). If the reviewers disagreed, consensus was reached among the whole review team.

Extraction strategy

The data were extracted by members of the review team. If articles were written in a language other than English, they were translated into English before extraction. In studies that compared two imaging techniques, results derived from the more precise technique were considered in our meta-analysis.

Outcomes of interest

The following data were extracted from these studies: the method of anatomical assessment (cadaver dissection, radiological imaging, or intraoperative assessment), geographical origin of the studied population, study sample, known health status of the patients in the study group, prevalence of the trunk of Henle, mean diameter and length of the trunk, and information on venous trunk tributaries. The diameter of the trunk was defined as the maximum measured diameter of the visualized vein.

Quality assessment

We used the AQUA tool to assess the quality of the included studies (Henry et al., 2017). The risks of bias in the reported anatomical data for the prevalence, diameter, and variations in the venous trunk of Henle were deemed "high," "low," or "unclear" by assessing each study using five domains (characterization of study target and subject, design of the research, characteristics of the methodology, expositive anatomy, and reporting of outcomes), which involved multiple questions evaluating various parameters. The answer "no" to any question in a particular domain meant a "high" grade for that domain. If the data were insufficient or vague, studies were designated "unclear."

Statistical analysis

Calculations were conducted using MetaXL analysis version 2.0 EpiGear Pty Ltd. (Wilston, Queensland, Australia) for the multi-categorical pooled prevalence of the anatomical attributes. Comprehensive Meta-Analysis version 3.0 by Biostat (Englewood, NJ) was used to analyze the morphometric data. The statistical analysis was based on a random effects model.

The results of the chi-squared test and the I^2 statistic indicated heterogeneity among the included studies. For the chi-squared test, Cochran's Q P-value <0.10 was assumed to indicate significant heterogeneity. For the I^2 statistic, the results were interpreted as follows: 0% to 40%—"might not be important," 30% to 60%—"could indicate moderate heterogeneity," 50% to 90%—"could indicate substantial heterogeneity," and 75% to 100% – "could represent considerable heterogeneity."

To identify factors potentially contributing to heterogeneity, patients were divided into subgroups on the basis of several criteria such as study type (cadaveric, imaging, and intra-operative), health status (healthy, colon cancer, and pancreatic diseases), and geographical origin (Europe, Asia, North America, and South America). The comparison of confidence intervals for any two rates indicated differences between the subgroups; if they overlapped, the difference was considered statistically insignificant (Higgins and Green, 2011; Henry et al., 2016).

RESULTS

Acquiring the studies

Our search identified 290 records. Reference screening of those studies yielded an additional 16 articles. After an eligibility assessment, a total of 38 studies were subjected to extraction and quantitative synthesis (meta-analysis). Figure 1 is a PRISMA flow-chart outlining the study inclusion process.

Quality of the included studies

There was a low risk for bias in the "design of the study" and "reporting of outcomes" domains. The risk of bias was rated high in the "target and subject attributed" domain, mostly because of missing baseline and demographic data concerning the study subjects. The "methodology description" domain was rated a high risk of bias in most studies because they lacked descriptions of the specialty or the experience of investigators involved. Some of the included articles contained no clear definition of the venous trunk of Henle (or gastrocolic trunk), so the risk of bias for the "descriptive anatomy" domain was rated high (Supporting Information Supplement 3).

Characteristics of the included studies

The characteristics of the included studies are presented in Table 1. Overall, data concerning n = 2,686 subjects were included in the meta-analysis (Descomps and De Lalaubie, 1912; Falconer and Griffiths, 1950; Couppié, 1957; Gillot et al., 1962; Chambon et al., 1979; Birtwisle et al., 1983; Mori et al., 1992; Crabo et al., 1993; Maeda, 1993; Zhang et al., 1994; Hommeyer et al., 1995; Ibukuro et al., 1996; Graf et al., 1997; Vedantham et al., 1998; O'Malley et al., 1999; Ito et al., 2000; Lange et al., 2000; Yamada et al., 2000; Yamaguchi et al., 2002; Ignjatovic et al., 2004, 2010; Jin et al., 2006, 2008; Matsuki et al., 2006; Sakaguchi et al., 2010; Walser et al., 2011; Khan et al., 2012; Li et al., 2013; Acar et al., 2014; Chi et al., 2014; Ogino et al., 2014; Cao et al., 2015; Miyazawa et al., 2015; Hu et al., 2016; Lee et al., 2016; Stelzner et al., 2016; Kuzu et al., 2017; Alsabilah et al., 2017b). The included studies were published between 1912 and 2016, and the cohorts were investigated on three different continents: Asia (18 studies, n = 1,489 subjects) (Maeda, 1993; Ibukuro et al., 1996; Yamada et al., 2000; Yamaguchi et al., 2002; Jin et al., 2006, 2008; Matsuki et al., 2006; Sakaguchi et al., 2010; Li et al., 2013; Acar et al., 2014; Chi et al., 2014; Ogino et al., 2014; Cao et al., 2015; Miyazawa et al., 2015; Hu et al., 2016; Lee et al., 2016; Kuzu et al., 2017; Alsabilah et al., 2017b), Europe (12 studies, n = 789) (Descomps and De Lalaubie, 1912; Falconer and Griffiths, 1950; Couppié, 1957; Gillot et al., 1962; Chambon et al., 1979; Birtwisle et al., 1983; Zhang et al., 1994; Lange et al., 2000; Ignjatovic et al., 2004, 2010; Khan et al., 2012; Stelzner et al., 2016), and North America (eight studies, n = 438) (Mori et al., 1992; Crabo et al., 1993; Hommeyer et al., 1995; Graf et al., 1997; Vedantham et al., 1998; O'Malley et al., 1999; Ito et al., 2000; Walser et al., 2011). There were 21 imaging studies (n = 1,589) (Mori et al., 1992; Crabo et al., 1993; Maeda, 1993; Zhang et al., 1994; Hommeyer et al., 1995; Ibukuro et al., 1996; Graf et al., 1997; Vedantham et al., 1998; O'Malley et al., 1999; Ito et al., 2000; Yamada et al., 2000; Matsuki et al., 2006; Jin et al., 2008; Sakaguchi et al., 2010; Walser et al., 2011; Khan et al., 2012; Li et al., 2013; Chi et al., 2014; Ogino et al., 2014; Miyazawa et al., 2015; Hu et al., 2016), 14 cadaveric studies

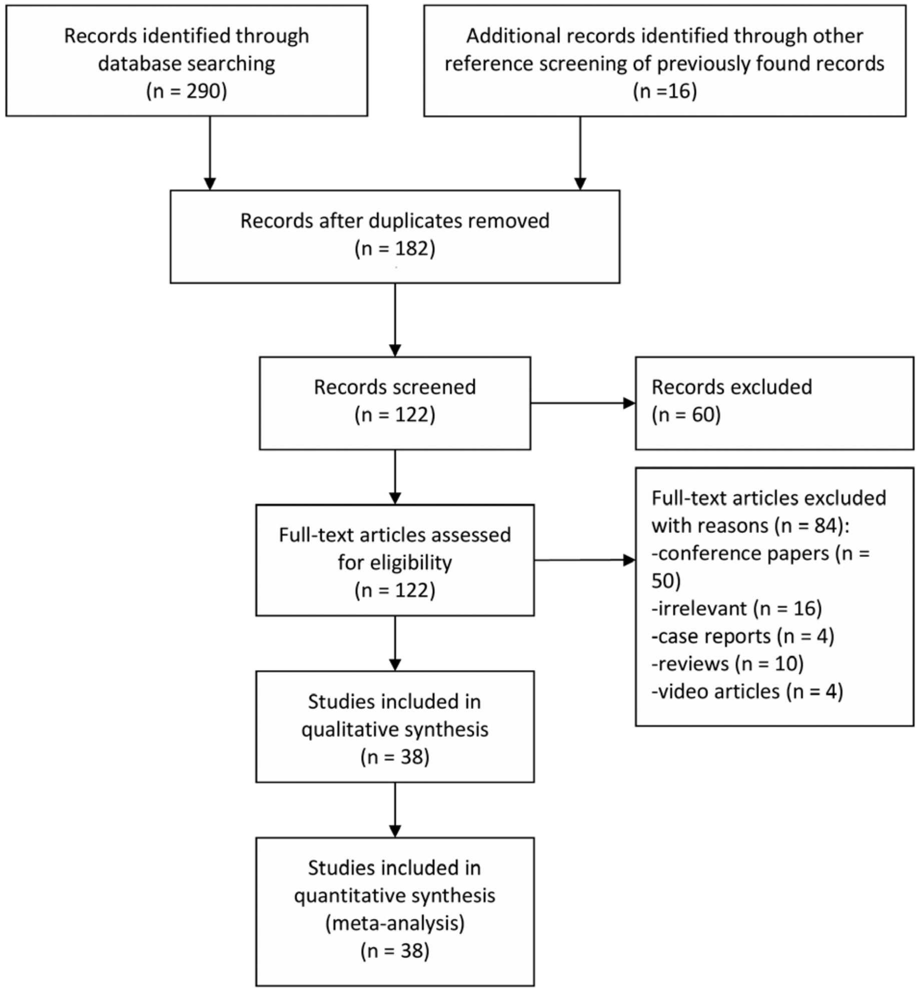

Fig. 1. Flow chart outlining the study inclusion process.

(*n* = 730 subjects) (Descomps and De Lalaubie, 1912; Falconer and Griffiths, 1950; Couppié, 1957; Gillot et al., 1962; Chambon et al., 1979; Birtwisle et al., 1983; Zhang et al., 1994; Yamaguchi et al., 2002; Ignjatovic et al., 2004, 2010; Jin et al., 2006; Acar et al., 2014; Stelzner et al., 2016; Kuzu et al., 2017), three intra-operative studies (*n* = 330) (Cao et al., 2015; Lee et al., 2016; Alsabilah et al., 2017b), and one mixed cadaveric and intra-operative study group in which the groups could not be differentiated (*n* = 37) (Lange et al., 2000). Data concerning healthy individuals were presented in 22 studies (*n* = 1,197) (Descomps and De Lalaubie, 1912; Falconer and Griffiths, 1950; Couppié, 1957; Gillot et al., 1962; Chambon et al., 1979; Birtwisle et al., 1983; Crabo et al., 1993; Maeda, 1993; Zhang et al., 1994; Ibukuro et al., 1996; Vedantham et al., 1998; Ito et al., 2000; Yamaguchi et al., 2002; Ignjatovic et al., 2004, 2010; Jin et al., 2006, 2008; Walser et al., 2011; Acar et al., 2014; Chi et al., 2014; Stelzner et al., 2016; Kuzu et al., 2017). Patients with pancreatic lesions were described in nine studies (*n* = 642) (Mori et al., 1992; Maeda, 1993; Hommeyer et al., 1995; Graf et al., 1997; Vedantham et al., 1998; O'Malley et al., 1999; Yamada et al., 2000; Chi et al., 2014; Miyazawa et al., 2015), and information regarding colon cancer patients was found in five papers (*n* = 452) (Khan et al., 2012; Ogino et al., 2014; Hu et al., 2016; Lee et al., 2016; Alsabilah et al., 2017b). Studies reporting data concerning patients diagnosed with alternative ailments (abdominal or pelvic malignancies, liver cirrhosis, portal hypertension, or unspecified conditions) were classified as "other conditions" in a stand-alone group that included seven studies (*n* = 395) (Ito et al., 2000; Lange et al., 2000; Matsuki et al., 2006; Sakaguchi et al., 2010; Khan et al., 2012; Li et al., 2013; Cao et al., 2015).

Prevalence of the venous trunk of Henle

Thirty-eight studies (*n* = 2,686) reported data on the prevalence of the venous trunk of Henle (Table 2). The pooled prevalence in all included studies was 86.9% (95% CI: 0.81–0.92) (Fig. 2). The pooled prevalence in the group of imaging studies was 89.9% (95% CI: 0.83–0.95), and in the joined intra-operative and

TABLE 1. Characteristics of included studies

Study	Country	Type of study	Number of subjects	Prevalence of trunk of Henle (%)
Acar et al. (2014)	Turkey	Cadaveric	12	91.7
Alsabilah et al. (2017a, 2017b)	South Korea	Intraoperative	70	88.6
Birtwisle et al. (1983)	France	Cadaveric	50	72.0
Cao et al. (2015)	China	Intraoperative	144	93.8
Chambon et al. (1979)	France	Cadaveric	50	56.0
Couppié 1957	France	Cadaveric	169	87.0
Crabo et al. (1993)	USA	Imaging	100	89.0
Descomps and De Lalaubie (1912)	France	Cadaveric	33	51.5
Falconer and Griffiths (1950)	UK	Cadaveric	50	100.0
Gillot et al. (1962)	France	Cadaveric	78	59.0
Graf et al. (1997)	USA	Imaging	54	87.0
Hommeyer et al. (1995)	USA	Imaging	86	87.2
Hu et al. (2016)	China	Imaging	84	89.3
Ibukuro et al. (1996)	Japan	Imaging	50	100.0
Ignjatovic et al. (2010)	Norway (*n* = 22), Serbia (*n* = 16), Switzerland (*n* = 4)	Cadaveric	42	81.0
Ignjatovic et al. (2004)	Serbia	Cadaveric	10	100.0
Ito et al. (2000)	USA	Imaging	72	95.8
Jin et al. (2008)	China	Imaging	50	68.0
Jin et al. (2006)	Japan	Cadaveric	9	88.9
Khan et al. (2012)	UK	Imaging	132	100.0
Kuzu et al. (2017)	Turkey	Cadaveric	111	100.0
Lange et al. (2000)	Netherlands	Intraoperative/cadaveric	37	46.0
Lee et al. (2016)	South Korea	Intraoperative	116	79.3
Li et al. (2013)	China	Imaging	26	73.1
Maeda (1993)	Japan	Imaging	176	48.3
Matsuki et al. (2006)	Japan	Imaging	20	100.0
Miyazawa et al. (2015)	Japan	Imaging	100	100.0
Mori et al. (1992)	Canada	Imaging	10	90.0
Ogino et al. (2014)	Japan	Imaging	81	87.7
O'Malley et al. (1999)	USA	Imaging	25	96.0
Sakaguchi et al. (2010)	Japan	Imaging	102	77.5
Stelzner et al. (2016)	Germany	Cadaveric	4	75.0
Vedantham et al. (1998)	USA	Imaging	72	91.7
Walser et al. (2011)	USA	Imaging	19	94.7
Chi et al. (2014)	China	Imaging	250	100.0
Yamada et al. (2000)	Japan	Imaging	30	100.0
Yamaguchi et al. (2002)	Japan	Cadaveric	58	69.0
Zhang et al. (1994)	France	Imaging/cadaveric	104	75.0

cadaveric groups it was 82.3% (95% CI: 0.73–0.90). The trunk was present among North Americans in 91.3% of cases (95% CI: 0.87–0.95), among Asians in 87.3% (95% CI: 0.79–0.94), and among Europeans in 82.9% (95% CI:0.71–0.93). Our analysis gave a pooled prevalence of 84.6% (95% CI:0.76–0.92) for the trunk of Henle among healthy individuals. Overall, 87.7% (95% CI:0.72–0.99) of patients suffering from pancreatic diseases and 92.3% (95% CI: 0.85–0.98) of those diagnosed with colon cancer had the venous trunk of Henle. Subjects included in the "other conditions" group had a pooled prevalence for the venous trunk of 88.5% (95% CI:0.75–0.99).

Diameter of the venous trunk of Henle

The mean diameter of the venous trunk of Henle with standard deviation was reported in only seven imaging studies (*n* = 664) (Crabo et al., 1993; Maeda, 1993; Vedantham et al., 1998; Ito et al., 2000; Yamada et al., 2000; Chi et al., 2014; Hu et al., 2016). Overall, the pooled mean diameter was 4.2 ± 0.2 mm (range: 2–7 mm). Computed tomography studies reported a higher mean diameter (4.3 ± 0.2 mm) than magnetic resonance imaging studies (4.0 ± 0.3 mm). Geographical analysis revealed that the diameter was 4.1 ± 0.9 mm among Asians and 4.0 ± 0.4 mm among North Americans. Healthy subjects had a pooled mean diameter of 3.9 ± 0.3 mm (range: 2–7 mm). Patients diagnosed with pancreatic disease (4.7 ± 0.3 mm) and those suffering from colon cancer (4.3 ± 0.1 mm) had wider venous trunks than healthy subjects, although the difference was not statistically significant (Table 3).

Length of the venous trunk of Henle

Only one study reported a mean length for the venous trunk of Henle with standard deviation, so no meta-analysis could be performed. The mean length

TABLE 2. Prevalence of venous trunk of Henle

Subgroup	Number of subjects	Number of studies	Pooled prevalence of trunk of Henle (%)	CI 95%	I^2 (%)	I^2 CI 95%	Cochrane's Q, P value
Overall	2686	38	86.9	0.81–0.92	94.12	92.77–95.21	<0.01
Imaging	1589	21	89.8	0.83–0.95	93.32	91.38–94.83	<0.01
CT	1248	18	87.6	0.8–0.94	92.89	90.63–94.61	<0.01
MRI	322	2	98.9	0.95–1	68.45	8.56–89.11	0.02
Intraoperative + Cadaveric	1097	18	82.3	0.73–0.90	91.90	88.69–94.20	<0.01
Intraoperative	330	3	87.7	0.78–0.96	83.47	49.98–94.54	<0.01
Cadaveric	730	14	82.8	0.72–0.93	92.27	88.73–94.69	<0.01
Intraoperative/ Cadaveric	37	1	46.0	0.3–0.62	–	–	–
Asia	1489	18	87.3	0.79–0.94	94.85	93.31–96.04	<0.01
North America	438	8	91.3	0.87–0.95	41.51	0.00–72.04	0.08
Europe	759	12	82.9	0.71–0.93	93.31	90.53–95.27	<0.01
Healthy	1197	22	84.6	0.76–0.92	92.16	89.5–94.14	<0.01
Pancreas disease	642	9	87.5	0.72–0.98	95.72	93.89–97.01	<0.01
Colon cancer	452	5	92.3	0.85–0.98	86.81	73.54–93.42	<0.01
Other conditions	395	7	88.6	0.75–0.99	92.04	86.16–95.42	<0.01

CT – computed tomography, MRI – magnetic resonance imaging

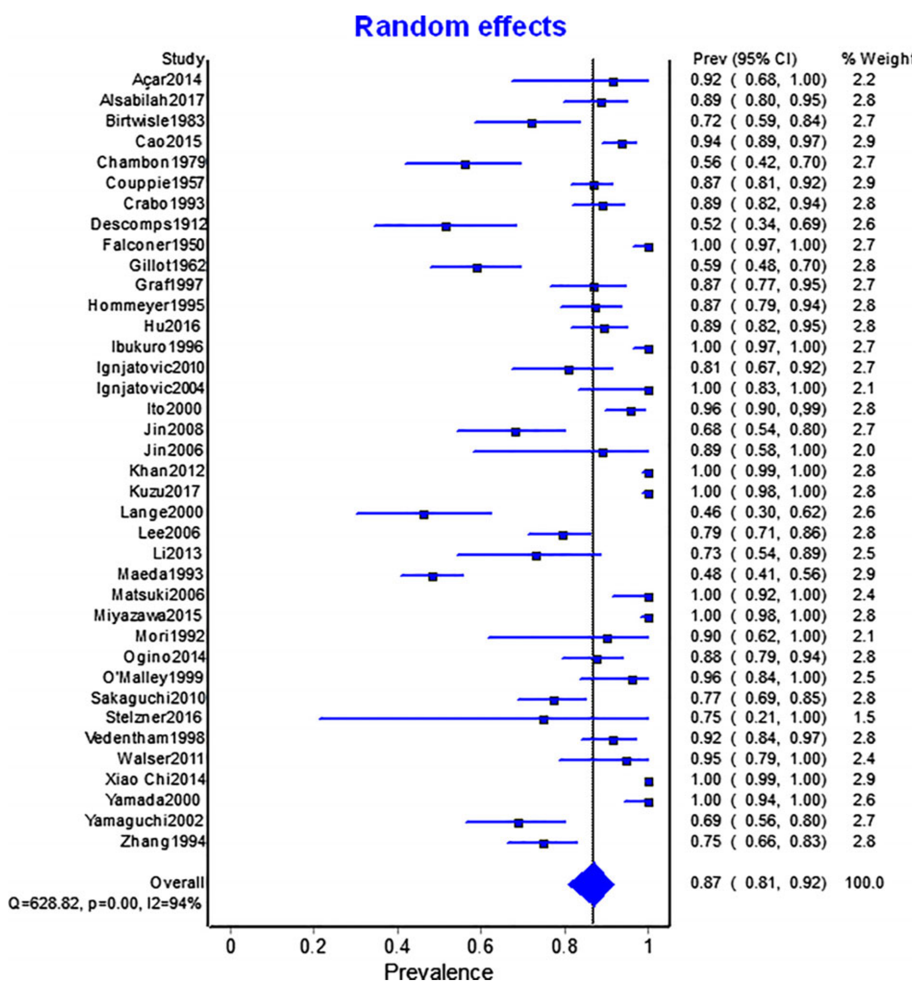

Fig. 2. Forest plot for the pooled prevalence of the venous trunk of Henle.

TABLE 3. Diameter of venous trunk of Henle

Subgroup	Number of subjects	Number of studies	Pooled mean diameter of trunk of Henle (mm)	Standard deviation	CI 95%	I^2(%)	Cochrane's *Q*, *P* value
Overall	664	7	4.2	0.2	3.87–4.55	96.1	0.00
CT	345	5	4.3	0.2	3.85–4.78	93.82	0.00
MRI	319	2	4.0	0.3	3.38–4.65	97.82	0.00
Asia	440	4	4.3	0.9	0.04–3.97	95.31	0.00
North America	224	3	4.1	4.0	0.15–3.2	96.29	0.00
Healthy	250	5	3.9	0.3	3.31–4.43	95.73	0.00
Pancreas disease	304	6	4.7	0.3	4.05–5.25	94.68	0.00
Colon cancer	75	1	4.3	0.1	4.07–4.53	–	–
Other conditions	35	1	3.5	0.2	3.14–3.86	–	–

CT – computed tomography, MRI – magnetic resonance imaging

according to the imaging study by Hu et al. was 10.7 ± 4.9 mm (range: 2.2–22.7 mm) (Hu et al., 2016).

Types of the venous trunk of Henle

The venous trunk of Henle can be formed by various combinations of three tributaries: gastric (always RGEV), colic, and pancreatic (variable) (Table 4). The most frequent type is gastro-pancreato-colic (56.1%, 95% CI: 0.34–0.77) (Fig. 3A) (Couppié, 1957; Gillot et al., 1962; Zhang et al., 1994; Lange et al., 2000; Ignjatovic et al., 2004, 2010; Jin et al., 2006; Acar et al., 2014; Cao et al., 2015; Miyazawa et al., 2015; Hu et al., 2016; Lee et al., 2016; Stelzner et al., 2016; Kuzu et al., 2017; Alsabilah et al., 2017b). The next most common is gastro-colic (17.8%, 95% CI: 0.02–0.42) (Fig. 3B) (Couppié, 1957; Gillot et al., 1962; Zhang et al., 1994; Lange et al., 2000; Yamaguchi et al., 2002; Ignjatovic et al., 2010; Sakaguchi et al., 2010; Ogino et al., 2014; Cao et al., 2015; Hu et al., 2016), followed by gastro-pancreatic (12.7%, 95% CI: 0.05–0.23) (Fig. 3C) (Zhang et al., 1994; Lange et al., 2000; Ignjatovic et al., 2004; Jin et al., 2006; Acar et al., 2014; Cao et al., 2015; Miyazawa et al., 2015; Hu et al., 2016; Lee et al., 2016; Kuzu et al., 2017; Alsabilah et al., 2017b). The pancreato-colic trunk is the least common type (0.9%, 95% CI: 0.00–0.02) (Fig. 3D) (Cao et al., 2015; Lee et al., 2016).

Representation of tributaries to the venous trunk

Tributaries to the venous trunk of Henle are represented by various colic and pancreatic veins. A total of 18 studies reported different types of colic or pancreatic tributaries (Couppié, 1957; Gillot et al., 1962; Zhang et al., 1994; Lange et al., 2000; Yamaguchi et al., 2002; Ignjatovic et al., 2004, 2010; Jin et al., 2006; Sakaguchi et al., 2010; Acar et al., 2014; Ogino et al., 2014; Cao et al., 2015; Miyazawa et al., 2015; Hu et al., 2016; Lee et al., 2016; Stelzner et al., 2016; Kuzu et al., 2017; Alsabilah et al., 2017b). A colic tributary can be represented by various veins, which often contribute jointly to the venous trunk. The most common representation of the colic tributary was the superior right colic vein (SRCV) (82.5%, 95% CI: 0.60–0.98) followed by the RCV (24.1%, 95% CI: 0.05–0.50) and middle colic vein (MCV) (12.7%, 95% CI: 0.05–0.23). Other colic tributaries are listed in Table 5.

The pancreatic tributary can include the anterior superior pancreaticoduodenal vein (ASPDV) at a pooled prevalence of 88.3% (95% CI:0.54–1.00) or the anterior inferior pancreaticoduodenal vein (AIPDV) (11.7%, 95% CI: 0.00–0.46).

Types of venous trunk confluences

The types of confluence reported in the literature are presented in Table 6. Our search revealed 42 different types forming the trunk of Henle (Couppié, 1957; Gillot et al., 1962; Zhang et al., 1994; Lange et al., 2000; Yamaguchi et al., 2002; Ignjatovic et al., 2004, 2010; Jin et al., 2006; Sakaguchi et al., 2010; Acar et al., 2014; Ogino et al., 2014; Miyazawa et al., 2015; Cao et al., 2015; Lee et al., 2016; Stelzner et al., 2016; Hu et al., 2016; Alsabilah et al., 2017b; Kuzu et al., 2017). The most frequently reported trunk confluence was RGEV + SRCV + ASPDV (17.8%, 95% CI: 0.29–0.79), followed by RGEV +

TABLE 4. Types of the venous trunk based on its tributaries

Type of the trunk	Number of subjects	Number of studies	Pooled prevalence (%)	CI 95%	I^2 (%)	I^2 CI 95%	Cochrane's *Q*, *P* value
Gastro-pancreato-colic	702	15	56.1	0.34–0.77	97.99	97.5–98.38	0.00
Gastro-colic	256	10	17.8	0.02–0.42	98.56	98.25–98.81	0.00
Gastro-pancreatic	164	11	12.7	0.05–0.23	94.57	92.69–95.96	0.00
Pancreato-colic	14	2	0.9	0.00–0.02	40.14	0.00–65.85	0.04

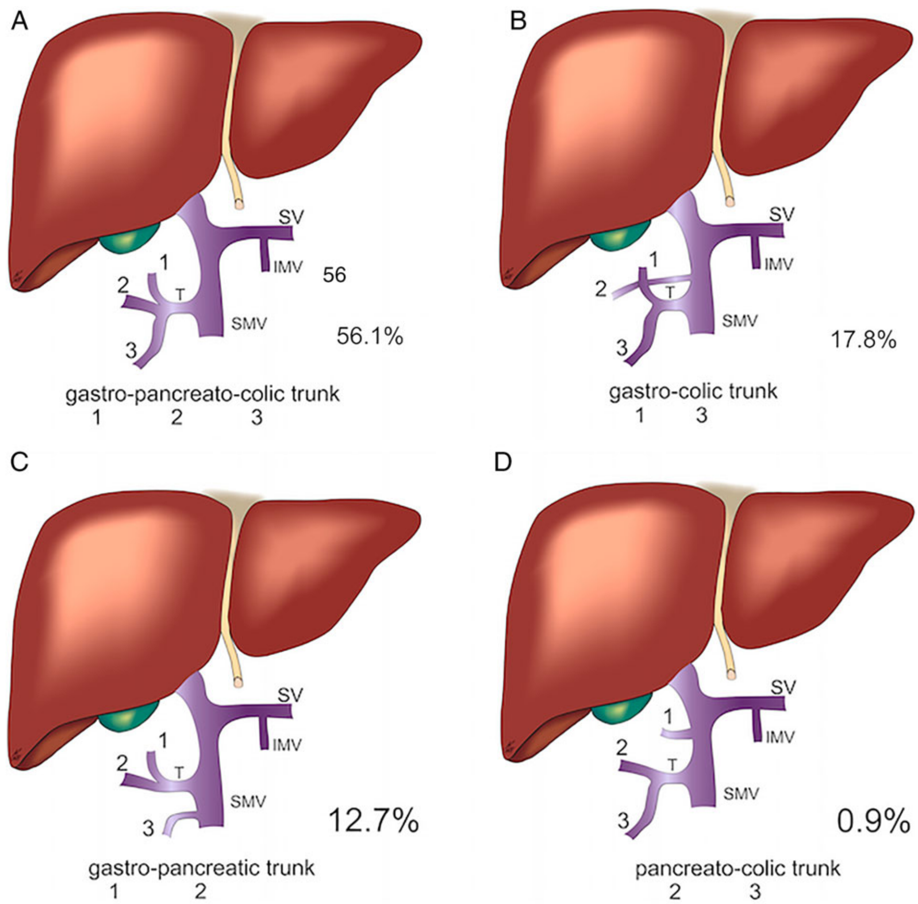

Fig. 3. Types of the venous trunk based on its tributaries. (**A**) Gastro-pancreato-colic trunk, (**B**) gastro-colic trunk, (**C**) gastro-pancreatic trunk, (**D**) pancreato-colic trunk. 1 – gastric tributary, 2 – pancreatic tributary, 3 – colic tributary, IMV– inferior mesenteric vein, SMV – superior mesenteric vein, SV – splenic vein, T – venous trunk of Henle.

TABLE 5. Representation of colic and pancreatic tributaries

Vein	Number of subjects	Number of studies	Pooled prevalence (%)	CI 95%	I^2 (%)	I^2 CI 95%	Cochrane's Q, P value
Colic tributary	855	17					
SRCV	664	14	82.5	0.60–0.98	97.87	97.32–98.30	<0.01
RCV	212	9	24.1	0.05–0.50	98.04	97.54–98.44	<0.01
MCV	121	11	12.7	0.05–0.23	92.46	89.32–94.67	<0.01
aMCV	28	2	2.3	0.00–0.07	87.11	80.63–91.42	<0.01
aSRCV	29	1	1.6	0.00–0.04	84.18	75.65–89.72	<0.01
RTCV	18	2	1.4	0.00–0.04	69.99	49.95–82.00	<0.01
MRCV	13	3	1.1	0.00–0.02	42.47	0.00–68.11	0.04
ICV	9	2	1.0	0.00–0.02	31.72	0.00–62.58	0.11
Pancreatic tributary	792	11					
ASPDV	614	10	88.3	0.54–1.00	99.14	98.94–99.31	0.00
AIPDV	186	3	11.7	0.00–0.46	99.14	98.94–99.31	0.00

SRCV – superior right colic vein, RCV – right colic vein, MCV – middle colic vein, aMCV– accessory middle colic vein, aSRCV – accessory superior right colic vein, RTCV – right transverse colic vein, MRCV – middle right colic vein, ICV – ileo-colic vein, ASPDV – anterior superior pancreaticoduodenal vein, AIPDV – anterior inferior pancreaticoduodenal vein

TABLE 6. Reported types of confluence

Variations	Number of subjects	Number of studies	Pooled prevalence (%)	CI 95%	I^2 (%)	I^2 CI 95%	Cochrane's *Q. P* value
RGEV + SRCV + ASPDV	194	7	54.8	0.29–0.79	95.38	92.61–97.12	<0.01
RGEV + ASPDV	153	10	33.5	0.19–0.49	92.38	88.06–95.13	<0.01
RGEV + SRCV + AIPDV	150	2	67.4	0.08–1.00	97.77	94.62–99.08	<0.01
RGEV + SRCV	76	7	16.2	0.04–0.34	93.89	89.80–96.34	<0.01
RGEV + RCV or SRCV + ASPDV	68	1	50.4	0.42–0.59	–	–	–
RGEV + SRCV + PDV	57	2	58.3	0.26–0.87	89.02	58.72–97.08	0.00
RGEV + RCV + ASPDV	56	2	26.9	0.05–0.56	92.02	72.52–97.68	<0.01
RGEV + RCV + SRCV + ASPDV	47	5	13.5	0.08–0.21	60.97	0.00–85.35	0.04
RGEV + RCV	40	3	19.1	0.00–0.53	95.94	91.26–98.11	<0.01
RGEV + RCV + SRCV	29	2	19.5	0.14–0.26	0.00	0.00–0.00	0.91
RGEV + SRCV + aSRCV + ASPDV	29	1	31.5	0.22–0.41	–	–	–
RGEV + aMCV	22	1	55.0	0.39–0.70	–	–	–
RGEV + RCV + MCV	22	1	31.0	0.21–0.42	–	–	–
RGEV + RCV or SRCV	19	1	14.1	0.09–0.20	–	–	–
RGEV + SRCV + MCV	16	3	7.2	0.03–0.14	55.90	0.00–87.41	0.10
RGEV + SRCV + MCV + ASPDV	15	2	13.7	0.08–0.21	0.00	–	0.53
SRCV + ASPDV	14	2	6.3	0.04–0.10	0.00	0.00–0.00	0.74
RGEV + MCV + PDV	14	1	18.7	0.11–0.28	–	–	–
RGEV + MCV	13	4	4.8	0.01–0.11	70.78	16.46–89.78	0.02
RGEV + SRCV + RTCV + AIPDV	13	2	9.2	0.00–0.26	88.25	55.00–96.93	0.00
RGEV + RCV + SRCV + MCV	12	2	7.4	0.02–0.16	60.67	0.00–90.84	0.11
RGEV + SRCV + MRCV + AIPDV	12	2	6.7	0.02–0.14	52.39	0.00–88.09	0.15
RGEV + SRCV + MCV + PDV	9	1	12.0	0.05–0.20	–	–	–
RGEV + RCV + MCV + ASPDV	6	2	3.7	0.01–0.07	0.00	–	0.98
RGEV + PDV	5	1	6.7	0.02–0.14	–	–	–
RGEV + MCV + ASPDV	5	3	3.0	0.01–0.06	4.23	0.00–90.04	0.35
RGEV + ASPDV + AIPDV	5	1	9.8	0.03–0.20	–	–	–
RGEV + RCV + aMCV + ASPDV	5	1	8.1	0.02–0.16	–	–	–
RGEV + RCV + SRCV + MCV + ASPDV	5	3	2.5	0.01–0.05	11.64	0.00–90.81	0.32

RGEV – right gastroepiploic vein, SRCV – superior right colic vein, RCV – right colic vein, MCV – middle colic vein, aMCV– accessory middle colic vein, aSRCV – accessory superior right colic vein, RTCV – right transverse colic vein, MRCV – middle right colic vein, ICV – ileo-colic vein, ASPDV – anterior superior pancreaticoduodenal vein, AIPDV – anterior inferior pancreaticoduodenal vein

ASPDV (14.0% 95% CI: 0.19–0.49) and RGEV + SRCV + AIPDV (13.7%, 95% CI: 0.08–1.00).

DISCUSSION

Our literature review and meta-analysis systematized current knowledge regarding the venous trunk of Henle, a significant component of the portal circulation. We included 38 original studies, which investigated over 2,500 subjects. This is the first study to summarize clinically relevant anatomical knowledge concerning the trunk of Henle in accordance with EBA principles. Our literature search identified only one previously published study that used a meta-analysis (Voiglio et al., 1998), and this was severely flawed owing to the small number of included patients (301) and the lack of adherence to PRISMA guidelines (the literature review was not systematic). Furthermore, the study by Voiglio et al., and other previous reviews of the literature, analyzed only the prevalence of the venous trunk of Henle and the veins contributing to the confluence (Zhang et al., 1994; Voiglio et al., 1998; Alsabilah et al., 2017a).

Overall, the trunk was very common (present in 86.9% of patients) (Fig. 2), with an average diameter of 4.2 mm. Hu et al. reported a short mean length (10 mm), although this was highly variable (2.2–22.7 mm). Therefore, we believe that the trunk of Henle is a short but relatively constant vessel that could be used routinely as a landmark during various abdominal procedures.

More than half of the reported types of venous trunk were gastro-pancreato-colic. The gastric tributary was always represented by the RGEV. The pancreatic and colic tributaries were represented by various veins and were most commonly identified as ASPDV and SRCV, respectively. Considering that the trunk has no colic component in 13.6% of cases and there is a pancreatic tributary in 69.7%, the name "gastro-colic trunk" (which is widely used to identify this structure) seems inaccurate. The "trunk of Henle" should be used instead.

This article summarizes data from 21 imaging studies, which revealed that the trunk of Henle has a pooled prevalence of 89.9%. This is comparable to the pooled prevalence of 82.3% derived from the 18 intraoperative and cadaveric studies included in this meta-analysis. Imaging studies using MRI reported a higher pooled prevalence (98.9%) than CT studies (87.6%). However, we found only two MRI studies, which could explain this discrepancy. The results from the intraoperative and cadaveric studies revealed comparable prevalences of the venous trunk (87.7% and 82.8%, respectively). The relatively high efficiency of radiological exploration of the anatomy can be explained by the difficulty of dissecting the pre-pancreatic tissues and the high risk of injuring or not finding appropriate blood vessels. A radiological assessment is limited only by the resolution of the acquired image. There was no statistically significant difference in the prevalence of the trunk of Henle among Asians, North Americans, and Europeans. The mean diameter of the trunk was also comparable between populations from Asia and North America. No available studies investigating Europeans reported a mean diameter for this structure.

According to Miyazawa et al., imaging of the drainage of the colic veins into the trunk of Henle provides useful information before pancreaticoduodenectomy (Miyazawa et al., 2015). Colorectal surgeons also benefit from preoperative radiological assessment of the vascular anatomy. Considering the trunk of Henle as an anatomical landmark helps to determine the position of the transverse mesocolon and to differentiate among the transverse mesocolon, gastrocolic ligament, and small intestine mesentery (Okino et al., 2001; Chi et al., 2014). Additionally, preoperative imaging allows for safe and efficient abdominal navigation during colectomy and reduces the risk of vascular injury (Zhang et al., 1994; Hu et al., 2016). In 2013, Kiil et al. described a rare case of a patient with a cecum adenocarcinoma who underwent a D3 right colectomy. Routine preoperative CT angiography revealed a confluence of the trunk of Henle with an aneurysm of the SMV, which helped to plan the procedure accordingly in advance (Kiil et al., 2013). Injury to the trunk of Henle and its tributaries during abdominal surgery (mostly gastric, colonic, and pancreatic procedures) can result in hemorrhaging and obscuring of the surgical field. This makes further progress difficult and dangerous. Blind clamping after avulsion of the veins contributing to the portal circulation (including the trunk of Henle) often exacerbates torrential bleeding owing to their relatively large diameters and lack of valves. In their surgical technique article, Samra and Smith reported that some trunk of Henle tributaries often retract into the head of the pancreas after being torn (Samra and Smith, 2003). Rare cases of trunk of Henle avulsion after abdominal trauma have been described. These cases presented with severe hemoperitoneum or a hematoma of the root of the transverse mesocolon or the gastrocolic ligament (Voiglio et al., 1998).

We also analyzed different subpopulations on the basis of the known health status of patients to assess the clinical significance of the trunk. The trunk of Henle was present in 84.6% of healthy individuals with a pooled mean diameter of 3.9 mm. Patients with pancreatic lesions presented with a trunk at a pooled prevalence of 87.7% and with a relatively large mean diameter (4.7 mm). Precise knowledge of the surgical anatomy and the appropriate identification of vascular structures are essential during pancreatic resections, including the Whipple procedure. Dissection of the infra-pancreatic tissues to identify the SMV should not be associated with ligation of the SRCV. Correct identification of the trunk of Henle, which is not done in regular practice, could allow for selective ligation of the RGEV and ASPDV (Kimura, 2000; Lange et al., 2000; Jin et al., 2006). The invasion of pancreatic cancer into the portal/superior mesenteric venous confluence can cause dilation of the trunk of Henle (Mori et al., 1992; Hommeyer et al., 1995). The identification of a dilated trunk can also indicate a pancreatic cancer that is not amenable to surgical treatment (O'Malley et al., 1999; Smith et al., 2007).

The trunk of Henle was identified in 92.3% of patients diagnosed with colon cancer. Its mean diameter in this group was 4.3 mm. Its anatomy is a key consideration during any colorectal surgery, especially when minimally invasive techniques are used where knowledge of the vascular anatomy must compensate for the lack of tactile feedback (Lee et al., 2016). Adequate visualization of the trunk and its tributaries during laparoscopic complete mesocolic excision helps achieve radical lymph node dissection, making it a safe and feasible surgical procedure for patients with transverse colon cancer (Ogino et al., 2014; Mori et al., 2015). Previously published data suggest that venous bleeding during colorectal surgery resulting from inappropriate traction of the transverse mesocolon can result from an avulsed trunk of Henle or injury to its tributaries (Ignjatovic et al., 2004; Kuzu et al., 2017). Knowledge concerning variations in the venous anatomy of the transverse colon should also prevent surgeons from incorrectly dissecting the trunk during transverse colectomy (Maki et al., 2016).

Patients in the "other conditions" group had a comparable prevalence (88.6%) and relatively small mean diameter (3.5 mm) of the trunk of Henle. Besides pancreatic and colorectal procedures, the trunk has proven relevant to other surgical ailments and operations. For instance, cases of extra-hepatic portal biliopathy could include acute angulation of the trunk (Mori et al., 2017). Surgical techniques involving living-donor liver transplantations for patients with portal vein thrombosis require initial identification of the trunk of Henle along with other major vessels contributing to the portal vein (Mizuno et al., 2012).

This study had several limitations. Previously published data were relatively heterogeneous and proposed several different anatomical definitions for the trunk of Henle. A subgroup analysis was conducted to identify potential sources of heterogeneity. A few of the original studies we included focused only on the confluence of the gastric and colic tributary as a "true gastrocolic trunk" (Birtwisle et al., 1983; Lange et al., 2000; Ignjatovic et al., 2010; Acar et al., 2014; Lee et al., 2016; Kuzu et al., 2017). The aim of our meta-analysis was to include the largest group of patients examined to date. Both gastro-colic and gastro-pancreatic confluences proved to be valuable landmarks and potential dangers during abdominal surgery. Therefore, both were classified in this study as part of the venous trunk. Another limitation was that only a few studies reported data concerning the diameter, length, and anatomical variations of the trunk of Henle. Further anatomical and clinical studies should be conducted to investigate these characteristics in a larger group of patients.

In conclusion, the trunk of Henle is a common variant of the portal circulation with a high prevalence of 86.9%. The venous trunk is a relatively short vessel with a diameter close to 4 mm. It is highly morphologically variable, but the most common type (gastro-pancreato-colic trunk, 56.1% prevalence) comprises three tributaries: gastric (represented by RGEV), pancreatic (represented by ASPDV), and colic (represented by SRCV). The trunk of Henle can be visualized during preoperative imaging, and an appropriate surgical approach has a high chance of success. It has value as a useful landmark during pancreatic or colorectal resections and various other abdominal procedures.

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CONFLICT OF INTEREST

None.

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