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The suspensory muscle of the duodenum and its nerve supply

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INTRODUCTION

The suspensory muscle of the duodenum was first described by Treitz (1853) who stated that it arose from the duodeno-jejunal flexure and a part of the inferior transverse portion of the duodenum and was inserted into the connective tissue surrounding the stems of the superior mesenteric and coeliac arteries. He also described a slip of the diaphragm (*Hilfsmuskel*) which arose from the right border of the oesophageal opening in the diaphragm and extended caudally to the region of the termination of the suspensory muscle of the duodenum. He did not apparently regard these two muscles as being the two bellies of a digastric muscle. However, since then several authors have described the *Hilfsmuskel* and the suspensory muscle of the duodenum as two parts of a single muscle (Lockwood, 1889; Low, 1907; Crymble, 1910; Testut & Latarjet, 1952; Blount & Lachman, 1966; Warwick & Williams, 1973). Nevertheless, according to Jit (1952), the *Hilfsmuskel* and the suspensory muscle of the duodenum are separate entities, both developmentally and structurally.

The nerve supply of the muscle does not seem to have been investigated. Haley & Peden (1943) and Haley & Perry (1949), however, supposed that its nerve supply is similar to that of the gut.

In the present paper an attempt has been made to find out: (*a*) whether the muscle is digastric with an upper striated portion, and a lower non-striated portion, (*b*) the manner of attachment of the suspensory muscle to the duodenum, (*c*) whether it is the longitudinal or the circular muscle coat of the duodenum which is continuous with the suspensory muscle, and (*d*) the nerve supply of the muscle. The nomenclature adopted is that used by Treitz (1853) and Jit (1952).

MATERIALS AND METHODS

The suspensory muscle of the duodenum and the *Hilfsmuskel* were dissected in the cadavers of 88 adults between 20 and 70 years of age, in 5 children, in 1 infant and in 6 neonates. Except in the case of the neonates, the material was obtained from medico-legal post-mortem subjects. Of these, the two muscles were removed from ten adults and processed for paraffin sectioning; the margin of the diaphragm giving attachment to the *Hilfsmuskel* was also included in the block. The site of attachment of the suspensory ligament to the duodenum was incorporated in a second block. Sections at 10–15 μm were stained using haematoxylin and eosin, Masson's trichrome,

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Verhoeff's for elastic fibres and Romanes' (1946), Holmes' (1947) and Palmgren's (1948) silver methods for nerve fibres.

In another series consisting of one neonate, an eight months infant and six adults, the region containing the two muscles, from the oesophageal hiatus to the superior wall of the duodenum, was cut out *en bloc*, fixed and stained by de Castro's technique. After staining, each specimen was divided transversely just above the level of the origin of the coeliac artery and the two parts embedded in paraffin. Serial coronal sections from 15 to 30 μm were cut and studied.

In two adults the suspensory muscle of the duodenum was stained by the technique of Gutmann & Sanders (1943) for identification of myelinated nerve fibres in serial transverse sections cut at 8 μm. In a further five adults the *Hilfsmuskel*, the suspensory muscle of the duodenum, and the origins of the coeliac and superior mesenteric arteries were dissected out *en bloc* and embedded in paraffin; serial coronal sections cut at 15 μm were stained for elastic fibres by Verhoeff's and aldehyde fuchsin techniques.

OBSERVATIONS

Gross anatomy (Figs. 1–4)

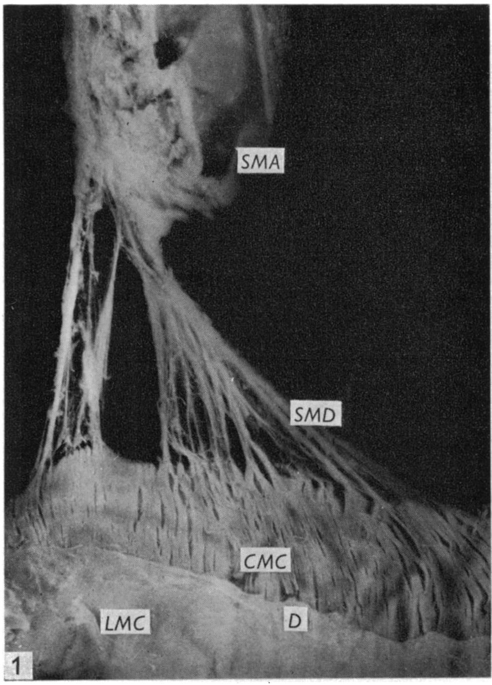
In all the 100 specimens dissected the suspensory muscle of the duodenum could be defined as a triangular muscle with its base attached caudally to the duodenum and its apex cranially in the region of the origins of the superior mesenteric and coeliac arteries. The muscle was usually attached to the third and fourth parts of the duodenum, sometimes to the duodeno-jejunal flexure in addition. By gross dissection it has been possible to show that the muscle is continuous with both the circular (Fig. 1) and longitudinal muscle coats of the duodenum. In 78 % of cases the cranial attachment of the suspensory muscle was to the connective tissue on the sides and root of the superior mesenteric artery and to the left side and root of the coeliac artery; in 17 % the muscle extended only up to the superior mesenteric artery. In 5 % the muscle was attached only on the left side of the coeliac artery. The sites of attachment of the muscle to the duodenum as found in 100 specimens is given in Table 1.

Fig. 1. Suspensory muscle of the duodenum (*SMD*) seen from its posterior aspect. The longitudinal muscle coat (*LMC*) has been partly removed from the duodenum (*D*). The circular muscle coat (*CMC*) of the duodenum is seen to be continued into the suspensory muscle of the duodenum which is continuous with the connective tissue on the left of the stem of the superior mesenteric artery (*SMA*). × 1.

Fig. 2. The *Hilfsmuskel* (*H*) and suspensory muscle of the duodenum (*SMD*) as separate structures. No continuity between their insertions, even by connective tissue, is visible. The suspensory muscle is attached cranially in the region of the stems of the superior mesenteric (*SMA*) and coeliac arteries (*CA*). × 4/5.

Fig. 3. The *Hilfsmuskel* (*H*) and the suspensory muscle of the duodenum (*SMD*) as separate structures. The *Hilfsmuskel* is attached above and left of the origin of the coeliac artery (*CA*) whereas the suspensory muscle of the duodenum (*SMD*) is attached to the connective tissue around the superior mesenteric artery (*SMA*). The two muscles are partly connected by some fibres which are indicated by an arrow. × 2/3.

Fig. 4. Absence of *Hilfsmuskel*. The suspensory muscle (*SMD*) is attached to the connective tissue on the under surfaces of the stems of the superior mesenteric (*SMA*) and coeliac arteries (*CA*). × 2/3.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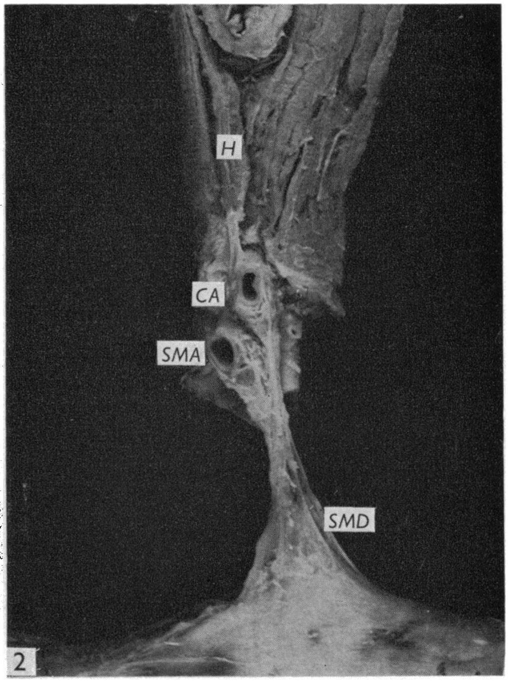
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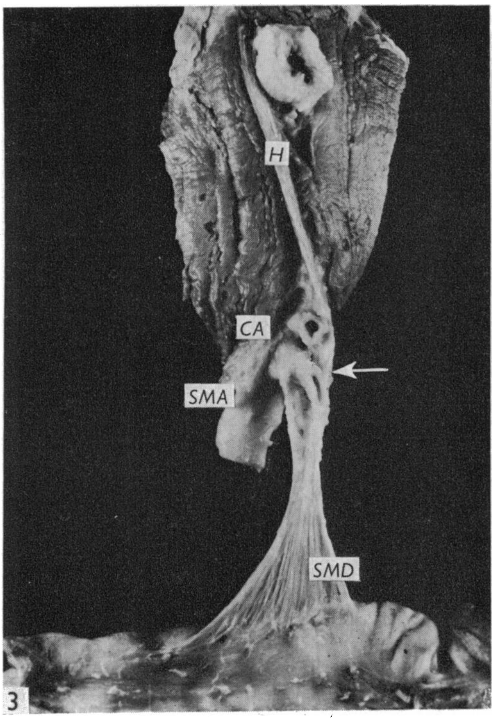
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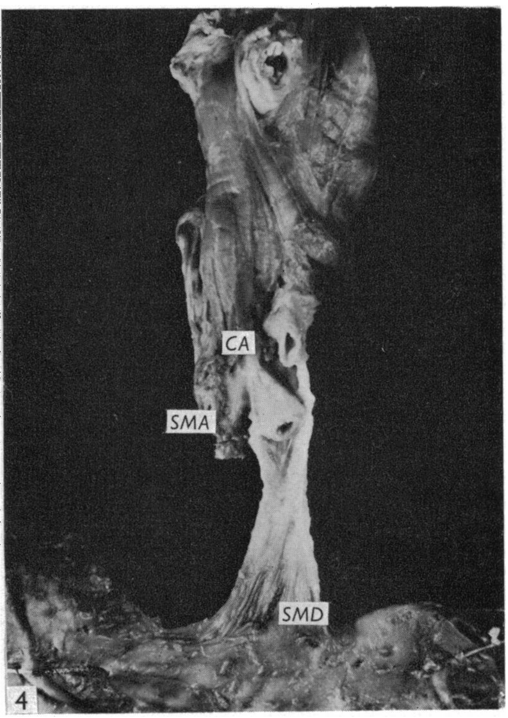
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Table 1. *Sites of attachment of the suspensory muscle of the duodenum*

Attachments	Incidence (%)
To the third and fourth parts of the duodenum	53
To the third and fourth parts of the duodenum and the duodeno-jejunal flexure	40
To the third part of the duodenum only	4
To the fourth part of the duodenum and duodeno-jejunal flexure	2
To the second, third and fourth parts of the duodenum	1

Table 2. *Origin and insertion of the Hilfsmuskel*

Origin	Incidence (%)
From the right side of the oesophageal opening (Figs. 2, 3)	93
From the left side of oesophageal opening	3
From both sides of the oesophageal opening	3
Absent (Fig. 4)	1
Insertion	
Just above and left of stem of the coeliac artery (Fig. 3)	84
Left of the stem of the coeliac artery	9
Left of the stems of the coeliac and superior mesenteric arteries	6
Absent	1

The *Hilfsmuskel*, which was present in all instances except one (Fig. 4) was observed to be a slip of diaphragm which arose from the margin of the oesophageal hiatus and was inserted into the connective tissue close to the stem of the coeliac artery, sometimes extending down to the origin of the superior mesenteric artery. Table 2 gives the attachments of the muscle as seen in 100 dissections.

In 63 % of cases, some collagenous bundles united the upper attachment of the suspensory muscle and the lower of the *Hilfsmuskel*. Gross dissection did not show a digastric arrangement in any specimen.

Microscopic structure

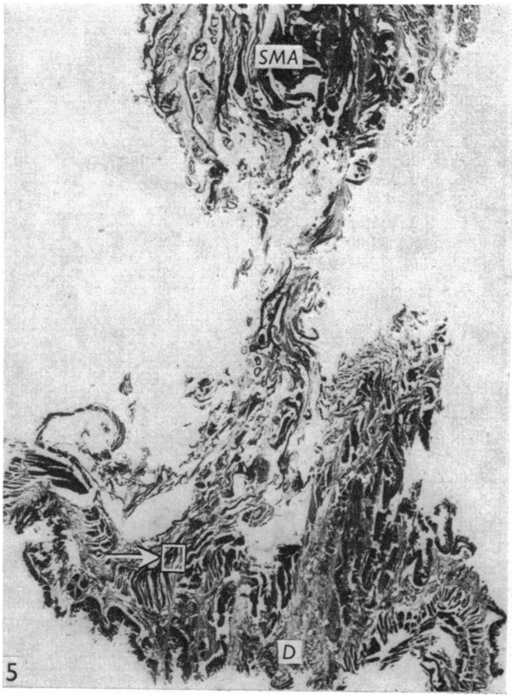
The triangular caudal part of the suspensory muscle of the duodenum contained plain muscle and collagen fibres, nerves and blood vessels. The muscle fibres were not specifically related to the nerve bundles or blood vessels. At its base, the fibres of the suspensory muscle were continuous with the longitudinal and circular muscle coats of the duodenum. Near its upper attachment, the smooth muscle fibres of the suspensory muscle were gradually replaced by collagenous and elastic fibres. As stated earlier, in some instances there was no continuity between the suspensory

Fig. 5. A coronal section of the suspensory muscle of the duodenum together with the duodenum (*D*) and superior mesenteric artery (*SMA*). An arrow indicates the inset shown in Fig. 6. de Castro. ×3·3.

Fig. 6. Inset from Fig. 5 showing muscular fibres and nerve bundles in the suspensory muscle of the duodenum. ×121.

Fig. 7. Inset from Fig. 6. Darkly stained nerve fibres are seen to supply the lightly stained plain muscle fibres of the suspensory muscle. ×555.

Fig. 8. Shows motor end plates in the striated *Hilfsmuskel*. de Castro. ×482.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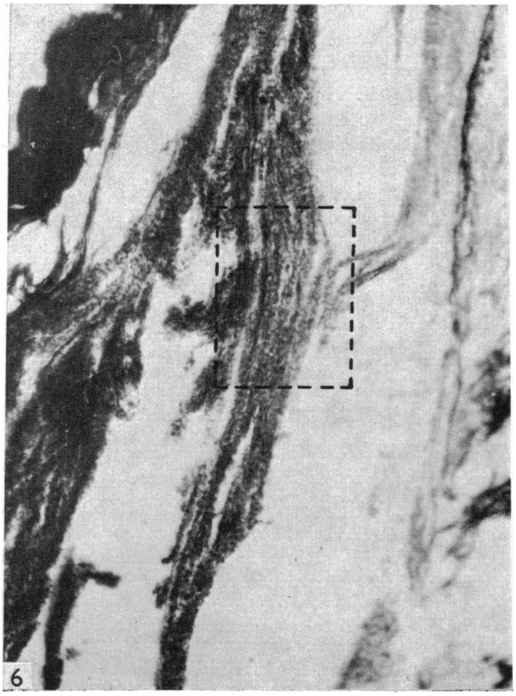
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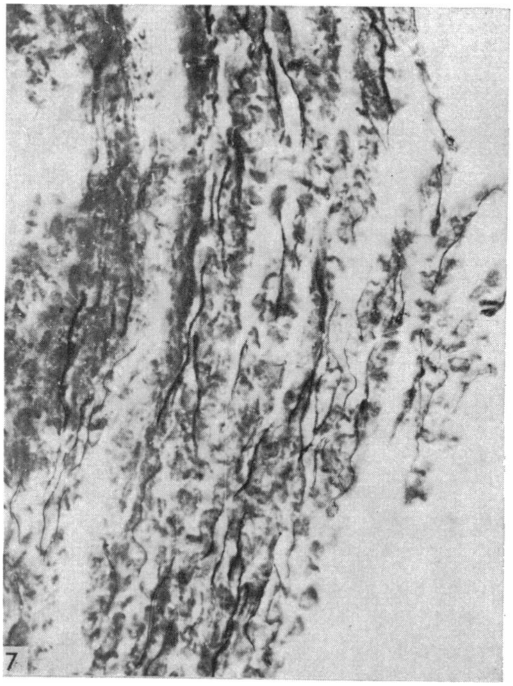
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muscle and the *Hilfsmuskel*. In others, some collagenous fibres, but not elastic fibres, united the two muscles. These did not, however, constitute an intermediate tendon.

The *Hilfsmuskel* consisted entirely of striated muscle fibres, like the rest of the diaphragm. It was inserted by collagenous fibres; elastic fibres were absent.

Nerve supply

Several large nerve bundles passed from the coeliac and superior mesenteric plexuses into the suspensory muscle of the duodenum (Figs. 5–7). These nerve bundles were not specifically related to the fine branches of the superior mesenteric artery which also extended into this muscle. The nerve bundles contained both myelinated and non-myelinated fibres. On their way caudally the non-myelinated fibres supplied branches to the plain muscle fibres of the suspensory muscle of the duodenum. Fibres from Auerbach's plexus were not seen to supply this muscle.

Serial sections of de Castro material showed that the nerve fibres supplying the diaphragm extended into the *Hilfsmuskel* and supplied it. The presence of motor end plates, although atypical (Fig. 8), at the termination of the nerve fibres in the *Hilfsmuskel*, indicated they were motor nerves and presumably were branches of the phrenic nerve.

DISCUSSION

From a study of material from 35 embryos, fetuses and neonates and from 2 adults, Jit (1952) confirmed the findings of Treitz (1853) that the suspensory muscle of the duodenum and the *Hilfsmuskel* were separate structures which were attached to the connective tissue in the region of the stems of the coeliac and superior mesenteric arteries. He refuted earlier statements (Lockwood, 1889; Low, 1907; Crymble, 1910) that the said muscles constituted a single muscle which arose from the right crus of the diaphragm and was inserted into the duodeno-jejunal flexure. He also showed that the two muscles were separate entities developmentally. Further, according to him, the *Hilfsmuskel* was a part of the diaphragm, whereas the suspensory muscle of the duodenum was continuous with the longitudinal muscle coat of the duodenum.

Haley & Peden (1943) and Haley & Perry (1949) dissected the suspensory muscle of the duodenum in 77 and 64 cadavers respectively. According to them the suspensory muscle of the duodenum arises from the right crus of the diaphragm and from the dense fibrous tissue around the coeliac artery is inserted into the duodenum. As they do not mention the exact attachment of the muscle to the right crus of the diaphragm, it appears that they did not trace the *Hilfsmuskel* from its origin at the oesophageal hiatus.

Argème, Mambrini, Lebreuil & Guérinel (1970) dissected the suspensory muscle of the duodenum in 40 cadavers. They also made a microscopic examination of their material, the extent of which was not indicated. According to them, an intermediate tendon was seen between the two muscles in 33 instances (82·5 %); in 2 specimens (5 %) there was no continuity at all and in another 5 instances (12·5 %), the *Hilfsmuskel* was absent. However, they called this a false digastric muscle ('pseudo-muscle digastrique') and agreed with Jit (1952) that the two muscles were separate entities, the insertions of which were joined by 'exchange of collagen fibres'. They did not mention the existence of elastic fibres in the intermediate portion. Costacurta (1972) studied the suspensory muscle of the duodenum macroscopically in 50 white and 50 black Brazilian cadavers, and examined 24 of the muscles histologically. According to him, although the suspensory muscle of the duodenum was found to be attached in the region of the superior mesenteric and/or coeliac arteries in 99 % of instances, some fibre-elastic fasciculi were seen to reach one or more muscular expansions (including the *Hilfsmuskel*) of the diaphragm in 65 % of dissections.

The present findings show that the suspensory muscle of the duodenum is attached cranially to the connective tissue in the region of the stems of the superior mesenteric and coeliac arteries, and the *Hilfsmuskel*, which arises from the diaphragm in the region of the oesophageal hiatus, is inserted into the connective tissue at the stem of the coeliac artery, sometimes extending to the stem of the superior mesenteric artery. In 63 % of cases some collagenous bundles united the insertions of the two muscles, but no connexion was detected in the remaining 37 %.

Sufficient evidence is now available to show that the two muscles are separate entities developmentally (Jit, 1952), structurally and macroscopically. Attachment of the suspensory muscle of the duodenum exclusively to the duodeno-jejunal flexure, although reported by Haley & Peden (1943) in 5·2 % and by Haley & Perry (1949) in 7·8 % of cases, has not been seen by Argème, Mambrini, Lebreuil & Guérinel (1970), Costacurta (1972) or by the present workers. It appears that exclusive attachment to the flexure, if it occurs at all, is rare.

Haley & Peden (1943) found the suspensory muscle of the duodenum to be attached to the third and fourth parts of the duodenum and to the flexure in 61 % of the material, and to the third and fourth parts of the duodenum alone in 15·6 %. In Haley & Perry's (1949) series of 64 dissections it was attached to the third and fourth parts of the duodenum and to the flexure in 32; in 20 the muscle was attached to the third and fourth parts but did not reach the flexure. Argème *et al.* (1970) found the muscle to be attached to the third and fourth parts in all cases, reaching the flexure in 60 %. In Costacurta's (1972) 100 dissections the muscle was attached to the flexure and the fourth part of the duodenum in 74, and to the third part in addition in 26. In the present series the attachment was confined to the third and fourth parts in 53 %, extending to include the flexure in a further 40 %. Contrary to the observation of Romanes (1968) the muscle was seen to be well developed even in subjects of 60 years of age.

Haley & Peden (1943) and Haley & Perry (1949) examined the 'suspensory ligament' of the duodenum histologically in 95 subjects and failed to detect any muscle fibres in thirteen. Other workers (Jit, 1952; Argème *et al.* 1970; Costacurta, 1972) identified muscle fibres in all material examined microscopically.

Jit (1952) and Argème *et al.* (1970) confirmed the observation of Treitz (1853) that the suspensory muscle of the duodenum represented its pulled-out longitudinal muscle coat. The present findings, however, agree with those of Haley & Perry (1949) and Costacurta (1972) that the circular muscle coat of the duodenum also contributes to the formation of this muscle. Attempts to prove in the present study that the longitudinal muscle coat is present only at the margins of the muscle, while the circular muscle coat is confined to the central portion (Costacurta, 1972), have not been successful. Contrary to the observations of Low (1907) and Crymble (1910), only unstriped muscle fibres were found in the suspensory muscle. This is in conformity with the views of Haley & Perry (1943), Haley & Peden (1949), Jit (1952), Argème *et al.* (1970) and Costacurta (1972).

As a separate entity, the *Hilfsmuskel* has been described by Treitz (1853) and Jit (1952). The latter confirmed the observation of Treitz (1853) that the muscle usually arises from the right margin of the oesophageal opening in the diaphragm. Argème *et al.* (1970) found that the muscle arose from the right side of the oesophageal opening or from its floor, but in one-third of their specimens it had an additional origin from the left side of the oesophageal hiatus. They also recorded that the muscle was absent in 12·5 % of cases. In the present material the muscle has been found to arise in 93 % of cases from the right side of the oesophageal opening and was completely absent in 1 %. The muscle consisted only of striated muscle fibres. As described by Jit (1952) this muscle can be considered as an additional attachment of the diaphragm to the connective tissue in the region of the coeliac artery.

As regards the function of the suspensory muscle of the duodenum, it may be stated that since it is usually (53 %) attached to the third and fourth parts of the duodenum, by its contraction it will open out the angle at the duodeno-jejunal flexure and thus facilitate the passage of the duodenal contents into the jejunum. The same may be its function in those instances where the major attachment of the muscle is to the third and fourth parts of the duodenum but with some attachment extending to the flexure (40 %). As no case has been seen where the muscle is attached only to the flexure, the possibility of this muscle making the angle of the flexure more acute by its contraction does not arise.

The present workers agree with Treitz (1853) that the *Hilfsmuskel* counteracts the pull of the suspensory muscle of the duodenum at the coeliac ganglia and the stems of the coeliac and superior mesenteric arteries.

SUMMARY

The gross anatomy, microscopic structure and nerve supply of the suspensory muscle of the duodenum and *Hilfsmuskel* have been studied in cadavers of 88 adults, 5 children, 1 infant and 6 neonates. The suspensory muscle of the duodenum, consisting of plain muscle fibres, arose from the connective tissue around the stems of the coeliac and superior mesenteric arteries. It was inserted into the third and fourth parts of the duodenum in 53 %, and into the duodeno-jejunal flexure in addition in 40 %. It was innervated by non-myelinated fibres arising from the coeliac and superior mesenteric plexuses. Although both the longitudinal and circular muscle coats of the duodenum extended into the suspensory muscle, it was not supplied by Auerbach's plexus.

The *Hilfsmuskel*, which is a slip of the diaphragm, is attached above to the margin of the oesophageal hiatus and below to the connective tissue in the region of the stem of the coeliac artery, sometimes extending to the stem of the superior mesenteric artery. The *Hilfsmuskel* and the suspensory muscle of the duodenum are separate entities.

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