

# Level of Arterial Ligation in Rectal Cancer Surgery: Low Tie Preferred over High Tie. A Review

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Consensus does not exist on the level of arterial ligation in rectal cancer surgery. From oncologic considerations, many surgeons apply high tie arterial ligation (level of inferior mesenteric artery). Other strategies include ligation at the level of the superior rectal artery, just caudally to the origin of the left colic artery (low tie), and ligation at a level without any intraoperative definition of the inferior mesenteric or superior rectal arteries.

Publications concerning the level of ligation in rectal cancer surgery were systematically reviewed. Twenty-three articles that evaluated oncologic outcome (n=14), anastomotic circulation (n=5), autonomous innervation (n=5), and tension on the anastomosis/anastomotic leakage (n=2) matched our selection criteria and were systematically reviewed. There is insufficient evidence to support high tie as the technique of choice. Furthermore, high tie has been proven to decrease perfusion and innervation of the proximal limb. It is concluded that neither the high tie strategy nor the low tie strategy is evidence based and that low tie is anatomically less invasive with respect to circulation and autonomous innervation of the proximal limb of anastomosis. As a consequence, in rectal cancer surgery low tie should be the preferred method.

**KEY WORDS:** Total mesorectal excision; Rectal cancer; High tie; Low tie; Central arterial ligation; Inferior mesenteric artery.

The most important prognostic factor for survival after rectal cancer surgery is represented by both distant metastasis and lymph node involvement. With respect to lymph node involvement, in 1908 Miles developed the abdominoperineal resection procedure for rectal cancer, incorporating transabdominal removal of lymphatic tissue. Believing that the route of lymphatic drainage of the rectum would follow its arterial supply, he recommended division of the superior rectal artery (SRA) just distally to

the origin of the left colic artery (LCA; low tie; Fig. 1), with subsequent *en bloc* excision of nodes and bowel below.<sup>1</sup> Within the same year Moynihan<sup>2</sup> first proposed resection of the inferior mesenteric artery (IMA) at its origin (high tie; Fig. 1), including the apical group of lymph nodes within the resection. During subsequent years, the high tie principle was further advocated by several authors.<sup>3-7</sup> However, according to the National Cancer Institute of the United States of America, an appropriate proximal lymphatic resection for rectal cancer without clinical evident lymph node disease is provided by the removal of the blood supply and lymphatics up to the level of the origin of the primary feeding vessel.<sup>8</sup> For rectal cancer this is at the origin of SRA (low tie), which is immediately distal to the offspring of LCA. However, the key report on which this guideline is based is represented by the study by Rouffet *et al.*<sup>9</sup> which is a trial on colon, not rectal, carcinoma. Actually, the level at which the artery is ligated in operations for rectal cancer varies greatly, depending largely on the surgeon.<sup>4,10-16</sup> In daily practice only a minority of surgeons dissect the origin of LCA to estimate the level of arterial ligation with respect to IMA and SRA with certainty. Furthermore, in most publications on high tie and low tie, SRA is incorrectly denominated as IMA caudally to the origin of LCA. After Lanz and Wachsmut the artery caudally to the origin of LCA is denominated SRA and not IMA.<sup>17</sup> Most authors use the term “high tie” for every type of ligation of IMA at all levels of the 1-cm to 7-cm long artery, including “flush” ligation of IMA at its very origin at the aorta.

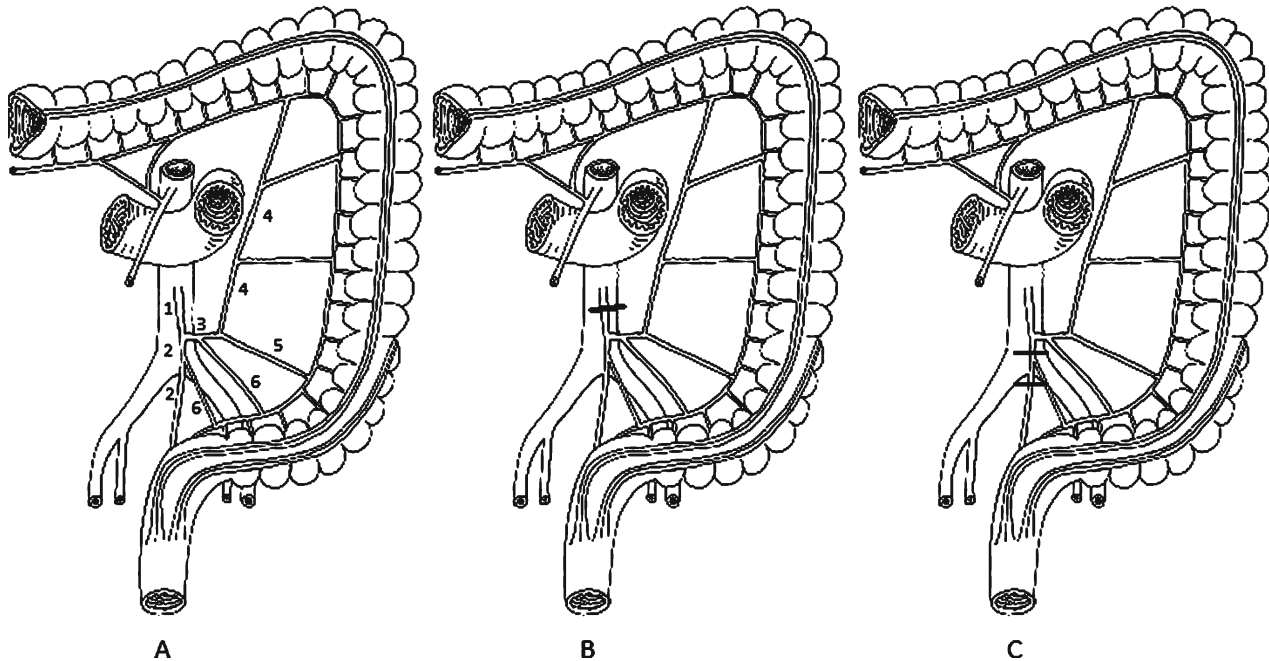
The choice of the level of arterial ligation in rectal cancer surgery can be based on three considerations: oncologic, anatomic, and technical. This article systematically reviews the evidence of possible benefits of high tie and low tie ligation techniques regarding these three different considerations.

## METHODS

A comprehensive literature search was conducted using PubMed and Cochrane database. The following terms were used: high ligation, high tie, low tie, and low ligation. In addition the terms IMA, SRA, or LCA were used in combination with colorectal cancer, rectal cancer, lymph

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**FIGURE 1.** Anatomic graph of vascular ligation techniques A. Inferior mesenteric artery (1), superior rectal artery (2), left colic artery (3), ascending limb of the left colic artery (4), descending limb of the left colic artery (5), sigmoid arteries (6). B. High tie. C. Low tie, cranially or caudally to the origin of the sigmoid artery (if present), but always caudally to the origin of the left colic artery.

node, circulation, flow, stump pressure, function, autonomous, nerve, and tension. We also hand searched references.

The publication time window was from 1980 to 2007. Studies were included for this review if it concerned a randomized, controlled trial or a cohort study (prospective/retrospective) that evaluated adult patients who underwent rectal resection with high tie or low tie or an anatomic study, describing the location of the autonomous nerve supply in relation with ligation technique. Review articles, letters, comments, conference proceedings, and case reports were not selected for this review. With respect to oncologic considerations outcomes of interest were survival, disease recurrence, and incidence of positive lymph nodes at the root of IMA. With respect to anatomic considerations outcomes of interest for effect on anastomotic circulation were tissue blood flow, tissue oxygen tension, and anastomotic leakage, and for effect on autonomous innervation were bowel and urogenital dysfunction and location of nerve supply in relation with the root of IMA. With respect to technical considerations outcomes of interest were length of the proximal limb, tension on the anastomosis, and anastomotic leakage. An assessment of the quality of the included studies was conducted according to the Oxford Centre for Evidence-based Medicine Levels of Evidence.

## RESULTS

No randomized, clinical trials comparing high tie and low tie were found.

In total 23 studies were selected for the three categories as follows:

1. Oncologic considerations: studies that concerned the influence of the level of arterial ligation on cancer prognosis and/or the incidence of lymph node metastasis at the root of IMA. In total 14 studies were selected (Table 1): 7 studies that compared high tie and low tie<sup>13-16,18-20</sup>; and 7 noncomparative studies.<sup>21-27</sup>
2. Anatomic considerations: studies that concerned the influence of the level of arterial ligation on anastomotic circulation (2A) and studies that concerned the influence of the level of arterial ligation on autonomous function (2B).
  - 2A) In total five studies were selected that concerned the influence of the level of arterial ligation on anastomotic circulation and/or anastomotic leakage rate (Table 2): two studies that compared high tie and low tie<sup>18,28</sup>; and three noncomparative studies.<sup>29-31</sup>
  - 2B) In total five studies that concerned the influence of the level of arterial ligation on autonomous innervation were selected (Table 3): one study that compared high tie and low tie<sup>32</sup>; and four noncomparative studies.<sup>33-36</sup>
- 3) Technical considerations: studies that concerned the influence of the level of arterial ligation on the length of the proximal limb of anastomosis. In total two studies were found, which are mentioned in Table 1 (Corder *et al.*<sup>18</sup> and Pezim and Nicholls<sup>14</sup>). Both studies compared anastomotic leakage rates between high tie and low tie and found no significant difference.

**Table 1. Overview of included studies concerning oncologic considerations of the level of arterial ligation**

Study	Level of evidence	Design	N	Tumor location	Procedure	Outcome measure	Results
Uehara <i>et al.</i> (2007) <sup>20</sup>	2b	Retrospective cohort	285	Rectum	High or low tie	Five-year survival; incidence of LN+	No significant difference; 1.9%
Kanemitsu <i>et al.</i> (2006) <sup>24</sup>	2b	Retrospective cohort	1,188	Colon and rectum	High tie	Incidence of LN+	1.7%
Kawamura <i>et al.</i> (2005) <sup>25</sup>	2b	Retrospective cohort	121	Rectosigmoid	High tie	Incidence of LN+	0.0% (only pT1 tumors)
Fazio <i>et al.</i> (2004) <sup>19</sup>	2b	Retrospective cohort	458	Rectum	High or low tie	Survival	No significant difference
Steup <i>et al.</i> (2002) <sup>27</sup>	2b	Retrospective cohort	605	Rectum	High tie	Incidence of LN+	0.3%
Kawamura <i>et al.</i> (2000) <sup>13</sup>	2b	Retrospective cohort	511	Colon and rectum	High or low tie	Disease-free survival	No significant difference
Hida <i>et al.</i> (1998) <sup>23</sup>	2b	Retrospective cohort	198	Rectum	High tie	Incidence of LN+	8.6%
Adachi <i>et al.</i> (1998) <sup>21</sup>	2b	Retrospective cohort	172	Rectosigmoid	High tie	Incidence of LN+	0.7%
Leggeri <i>et al.</i> (1994) <sup>26</sup>	2b	Retrospective cohort	252	Rectum	High tie	Incidence of LN+	4.0%
Corder <i>et al.</i> (1992) <sup>18</sup>	2b	Retrospective cohort	143	Rectum	High or low tie	Survival; recurrence	No significant differences
Dworak <i>et al.</i> (1991) <sup>22</sup>	2b	Retrospective cohort	424	Rectum	High tie	Incidence of LN+	1.0%
Surtees <i>et al.</i> (1990) <sup>16</sup>	2b	Retrospective cohort	250	Rectum	High or low tie	Survival rate	No significant difference
Pezim and Nicholls (1984) <sup>14</sup>	2b	Retrospective cohort	1,370	Rectosigmoid	High or low tie	Five-year survival	No significant difference

LN+ = positive lymph node at the root of inferior mesenteric artery.

**DISCUSSION**

**Oncologic Considerations**

Lymph node involvement is a major prognostic factor for survival after rectal cancer surgery. The high tie technique includes the apical group of lymph nodes at the root of IMA within the resection. However, the incidence of metastatic lymph nodes at the origin of IMA has been

reported to be relatively low in several studies, ranging from 0.3 to 8.6 percent.<sup>14,20,22,23,25-27</sup> Furthermore, Kanemitsu *et al.*<sup>24</sup> found no nodal metastases at the origin of IMA in patients with pT1 rectal tumors. This study suggested that low tie might be sufficient for pT1 sigmoid or rectal cancers. According to these findings, high tie might be beneficial only for patients with nodepositive disease. However, even in the case of

**Table 2. Overview of studies concerning the influence of the level of arterial ligation on anastomotic circulation**

Study	Level of evidence	Design	N	Procedure	Outcome measure	Results
Seike <i>et al.</i> (2007) <sup>31</sup>	2b	Prospective cohort	96	Rectal cancer resection with high tie	Tissue blood flow	Significant blood flow reduction after high techniques; high blood flow reduction in older, male patients
Dworkin <i>et al.</i> (1996) <sup>29</sup>	2b	Prospective cohort	26	Rectosigmoid resection	Tissue blood flow	Significant blood flow reduction after IMA ligation
Hall <i>et al.</i> (1995) <sup>28</sup>	2b	Prospective cohort	62	Colorectal resection with high or low tie	Tissue oxygen tension	No significant difference; tissue oxygen tension of sigmoid not adequate after both techniques
Kashiwagi <i>et al.</i> (1994) <sup>30</sup>	2b	Prospective cohort	13	IMA clamping	Tissue blood flow	No significant reduction
Corder <i>et al.</i> (1992) <sup>18</sup>	2b	Retrospective cohort	143	Rectal resection with high or low tie	Anastomotic leakage rate	No significant differences

IMA = inferior mesenteric artery.

**Table 3. Overview of studies concerning the influence of the level of arterial ligation on autonomous innervation**

Study	Level of evidence	Design	N	Procedure	Outcome measure	Results
Liang <i>et al.</i> (2007) <sup>34</sup>	2b	Prospective cohort	98	D3-resection (high tie)	Urogenital function	75.5% bladder and 91.7% sexual dysfunction
Sato <i>et al.</i> (2003) <sup>32</sup>	2b	Retrospective cohort	132	Rectal resection with high or low tie	Bowel function	High tie resulted in worse bowel function
Zhang <i>et al.</i> (2006) <sup>36</sup>	5	Anatomic study	16	Exploration inferior mesenteric plexus in cadavers	Location inferior mesenteric plexus	Inferior mesenteric plexus was never located at the root of IMA
Nano <i>et al.</i> (2004) <sup>35</sup>	5	Anatomic study	42	Exploration of left paraortic trunk in cadavers and patients undergoing rectal resection	Location left paraortic trunk	Left paraortic trunk was never located at the root of IMA
Hoer <i>et al.</i> (2000) <sup>33</sup>	5	Anatomic study	12	Isolation of inferior mesenteric plexus in cadavers	Location inferior mesenteric plexus	Inferior mesenteric plexus is invariably located at the root of IMA

IMA = inferior mesenteric artery.

nodepositive disease, it may be true that once the tumor has involved in these high lymph nodes, it has probably spread beyond. In this respect a factor could be represented by the generally poor prognosis of patients with rectal cancer with more than five involved lymph nodes who, if included in studies with high ligation, might obscure its value. Moreover, alternate lymphatic routes may frustrate attempts at tumor control by vascular ligation, regardless of the level of the tie. Tumors of the upper third of the rectum may drain along lymphatic channels that follow the portal vein and may be responsible for isolated lymphatic metastases within the hepatoduodenal ligament.<sup>37</sup> In the lower third of the rectum, drainage may occur laterally to the iliac nodes *via* lymphatics within the lateral ligaments.<sup>38</sup>

Three retrospective cohort studies on high tie reported advantageous results with significant five-year and ten-year survival data for the very limited groups of patients with positive lymph nodes at IMA.<sup>23,24,26</sup> We found the number of studies comparing high tie with low tie to be limited. All but one of these studies did not find any survival benefit after high tie in rectal cancer surgery.<sup>13–16,18–20</sup> Only Slanetz and Grimson<sup>15</sup> reported a stage-specific survival benefit of high tie in a retrospective study of 1,107 patients treated with high tie with extensive resection of mesenteric lymph drainage and 1,154 treated with low tie. However, this study did not eliminate the stage migration phenomenon, which may arise as a result of more accurate staging because of more extensive lymphadenectomy. Therefore, a proportion of patients might be assigned to a more advanced stage than would otherwise be the case, although their prognosis is the same. If this has occurred, the overall results in each stage would have improved and the proportion of patients in more advanced stages would have increased.<sup>39</sup>

Previous reports state that the number of harvested lymph nodes correlates significantly with long-term

results in patients with colorectal carcinoma, advocating the importance of pathologic examination of 12 or more nodes.<sup>40,41</sup> Limited lymph node dissection with preservation of IMA may result in a decreased number of harvested nodes. However, increasing the number of nodes by dissection of distant free nodes is considered to have no clinical impact.<sup>42</sup>

Most studies concerning high tie *vs.* low tie took place before the introduction of total mesorectal excision (TME) and neoadjuvant treatment for rectal cancer. Neoadjuvant treatment also has the potential to sterilize microscopic metastasis in nodes at the origin of IMA, undermining the rationale of high tie even more.<sup>43</sup> On the other hand, preoperative radiotherapy did not seem to prevent distant metastasis in the Dutch TME trial.<sup>44</sup> Possible benefit of high tie in combination with current surgical techniques and neoadjuvant treatment procedures needs to be investigated. In conclusion, assuming that reports on high tie procedures really reflect anatomically correct high tie dissections, there might be a small proportion of patients profiting from high tie. However, the amount and level of evidence for high tie is considered to be too modest for standardization of ligation of IMA.

### Anatomic Considerations

**Perfusion of the Proximal Limb of Anastomosis or Perfusion of Colostomy.** Consensus exists on the necessity of well-perfused anastomotic limbs. However, factors jeopardizing anastomotic circulation are not well known.

The low tie technique allows for adequate blood supply to the colon proximally to the anastomosis, whereas after high tie vascularization of the distal colon and sigmoid depends completely on the middle colic and marginal arteries.<sup>23,35</sup> The marginal artery arising from the middle colic artery is thought to be adequate for

sustaining the viability of the remaining colon.<sup>45,46</sup> However, despite most studies support this hypothesis, from preoperative measurements Dworkin *et al.* and Seike *et al.* concluded that high tie significantly reduces perfusion of the proximal limb.<sup>14,18,28,29,31</sup> Furthermore, because in many patients a decrease in systemic blood pressure occurs during the recovery phase after surgery, it is not excluded that in some cases pressure in the marginal artery is insufficient to maintain adequate blood flow to the colon limb despite the inherent tendency of “auto-regulation” in its vascular bed.<sup>47</sup> In correspondence with colon ischemia as a complication of IMA ligation in aorta surgery, especially in older patients with atherosclerotic vessels, ligation of IMA might result in hypoperfusion of the proximal limb.<sup>31,48</sup> In addition, in some patients deficits of the marginal artery might exist at the splenic flexure.<sup>48</sup> Kashiwagi *et al.*<sup>30</sup> reported on the necessity of a larger sigmoid resection in rectal carcinoma surgery when IMA was ligated. Consequently, mobilization of the splenic flexure would always be necessary.

Despite evidence for a decreased perfusion of the proximal limb after high tie exists, it can be concluded that until now the benefit of low tie concerning perfusion of the anastomosis has not been proven but it might be present in patients with atherosclerotic disease.

**Autonomous Innervation.** Preservation of the autonomous nervous system is important to prevent urogenital and anorectal dysfunction.<sup>49</sup> The paraortic trunks originate from the mesenteric plexus and descend along the aorta to join together and form the superior hypogastric plexus. If these are cut, ejaculation disorders and urinary incontinence may occur.<sup>50</sup> Therefore, in high tie it is important to identify the safest point of ligation of IMA to avoid autonomous nerve damage during surgery of rectal cancer. In the literature, disagreement exists concerning the relationship between the origin and the course of IMA and the autonomous nerve supply. Two anatomic studies conclude that the origin of IMA is the only safe point of ligation, whereas another found that the inferior mesenteric plexus forms a dense network around IMA to a distance of 5 cm from the aorta, suggesting that high tie leads to damage of the sympathetic nerves.<sup>33,35,51</sup> Two studies evaluated autonomic function after rectal resection. Liang *et al.*<sup>34</sup> reported urogenital dysfunction in the majority of patients after high tie. Sato *et al.*<sup>32</sup> compared patients who underwent rectal cancer resection before the implementation of low tie with patients who were treated after this implementation at the specific institution. Patients treated with high tie reported worse bowel function. Ligation of IMA at its origin disrupts the descending autonomic fibers and consequently leads to a long denervated colon segment, causing defecatory dysfunction.<sup>52</sup> However, until now insufficient evidence exists about whether low tie has a better prognosis with regard to autonomic function.

## Technical Considerations

**Length of the Proximal Limb of Anastomosis.** Apart from ischemia, tension on the anastomosis is thought to increase the risk of anastomotic leakage.<sup>23,35,53</sup> Some authors state that high tie often is indispensable to guarantee a tension-free anastomosis in low anterior resection.<sup>35,53,54</sup> With this technique the proximal limb is not withheld by an intact LCA-IMA-aorta axis.

However, a tension-free anastomosis also can be achieved in low tie resections by cutting the descending branch of LCA.<sup>18</sup> To our knowledge, there are no studies that evaluate the effect of different ligation techniques on anastomotic tension. The aforementioned publications of Pezim and Nicholls<sup>14</sup> and Corder *et al.*<sup>18</sup> suggest that critical length of the proximal limb is not an issue in low tie strategy. In addition, splenic flexure mobilization is not indicated routinely.<sup>55</sup>

## CONCLUSIONS

Since Miles and Moynihan respectively proposed low tie and high tie techniques for rectal carcinoma surgery in the same year (1908), until now the level of arterial ligation has been debated. The lack of prospective, randomized, clinical trials with sufficient follow-up in combination with an inconsistent methodology can be held responsible for this lack of consensus. In addition it is uncertain whether precise preoperative evaluation of anatomy has always been correct in the available studies that describe high tie and/or low tie ligation. High tie, because it has regained new interest in laparoscopy by its presumed advantage of easily creating mesenteric windows, is still advocated by many.<sup>51,54,56–59</sup> However, from our review there is insufficient evidence to support high tie as the technique of choice. Although the anatomic disadvantage of high tie concerning impaired perfusion and innervation of the proximal colon limb has not been proven sufficiently with regard to anastomotic leakage and bowel dysfunction until now, low tie is anatomically less invasive and is preferable to high tie in rectal cancer surgery.

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