Paradigm Academic Press
Journal of Innovations in Medical Research
ISSN 2788-7022
MAR. 2026 VOL.5, NO.1

The "Triangle Operation" in Pancreatic Cancer: Toward Optimizing Oncological Radicality After Neoadjuvant Therapy

Dr. R. Menoura[1], Dr. W. Tibermacine[2], Dr. B. Rais[1], Prof A. Ammari[3] & Prof A. Delmi[1]

[1] Surgery B Department, Constantine University Hospital, Algeria

[2] Radiology Department, Constantine University Hospital, Algeria

[3] Oncology Department, Didouche Mourad Hospital, Constantine, Algeria

Correspondence: Dr. R. Menoura, Surgery B Department, Constantine University Hospital, Algeria.

doi:10.63593/JIMR.2788-7022.2026.03.004

Abstract

Recent advances in pancreatic cancer management, particularly with the introduction of intensive neoadjuvant chemotherapy regimens, have significantly reshaped surgical indications and objectives. In this context, the "Triangle Operation," described by Thomas Hackert, has emerged as an innovative approach aimed at improving R0 resection rates without systematically resorting to arterial resections. This technique is based on an extensive dissection of the peri-arterial compartment located between the superior mesenteric artery, the celiac trunk, and the porto-mesenteric axis. Its primary goal is to eradicate areas of potential microscopic tumor spread, particularly after neoadjuvant therapy. Through a detailed analysis of anatomical foundations, technical principles, and clinical outcomes, this article highlights both the benefits and limitations of this strategy in the management of borderline resectable and locally advanced pancreatic tumors.

Keywords: superior mesenteric artery, superior mesenteric vein, celiac trunk, mesopancreas, retroportal lamina, unresectable adenocarcinoma

1. Introduction

Pancreatic cancer remains one of the most aggressive solid malignancies, with a five-year overall survival rate below 10% in most contemporary series, largely due to late diagnosis and a strong tendency for both locoregional and systemic spread (Siegel RL et al., 2023; Sung H et al., 2021). Surgery remains the only potentially curative treatment; however, it is limited by a high rate of positive resection margins, particularly at the retroportal margin and around peri-arterial structures (Verbeke CS et al., 2006; Esposito I et al., 2008).

The introduction of neoadjuvant chemotherapy protocols, especially FOLFIRINOX and gemcitabine-based combinations, has increased the number of patients eligible for secondary resection by reducing tumor burden and enabling better biological selection (Conroy T et al., 2018; Suker M et al., 2016; Janssen QP et al., 2019). However, after neoadjuvant therapy, evaluating tumor–vascular relationships remains challenging due to persistent dense fibrosis, making it difficult to distinguish residual viable tumor from post-treatment scarring (Ferrone CR et al., 2015; Cassinotto C et al., 2014).

In this setting, the need for systematic arterial resection has been questioned, given the significant morbidity associated with such procedures (Mollberg N et al., 2011). The "Triangle Operation" was therefore developed to achieve maximal oncological radicality through extensive peri-arterial dissection without arterial reconstruction (Hackert T et al., 2016; Hackert, T. et al., 2017).

2. Anatomical Basis and Oncological Rationale

Tumor spread in pancreatic cancer preferentially occurs along neural sheaths and vascular structures, particularly

around the superior mesenteric artery and the celiac trunk (Bapat AA et al., 2011; Ceyhan GO et al., 2009). Perineural invasion is observed in more than 70% of cases and represents a major predictor of local recurrence (Liebig C et al., 2009).

The anatomical compartment targeted by the "Triangle Operation" corresponds to a three-dimensional space bounded by the superior mesenteric artery, the celiac trunk, and the portal vein. This region includes the retroportal lamina, peri-arterial nerve plexuses, and deep lymphatic pathways, which are the primary sites of positive margins following standard pancreaticoduodenectomy (Hartwig W et al., 2013; Nagakawa T et al., 1996; Pedrazzoli S et al., 1998).

After neoadjuvant therapy, these structures frequently exhibit reactive fibrosis that may conceal residual viable tumor, thereby justifying systematic resection of this compartment to improve local disease control (Strobel O et al., 2019; Truty MJ et al., 2020).

3. Surgical Technique

The "Triangle Operation" involves a systematic and extensive dissection of the peri-arterial compartment. Following thorough exploration to exclude metastatic disease, the procedure begins with mobilization of the porto-mesenteric axis, followed by complete skeletonization of the superior mesenteric artery and the celiac trunk. This step requires a circumferential 360-degree dissection, allowing en bloc removal of all peri-arterial fibro-neural tissue (Hackert T et al., 2016; Inoue Y et al., 2015).

Pancreatic resection is subsequently performed according to tumor location, either as pancreaticoduodenectomy or distal pancreatectomy. The primary objective is to achieve a negative retroportal margin by removing all tissues at risk of microscopic invasion (Hackert T, Werner J & Büchler MW., 2018).

4. Oncological and Clinical Outcomes

Initial series reported by Hackert et al. demonstrated that the "Triangle Operation" could achieve R0 resection rates of up to 80–90% in selected patients following neoadjuvant therapy (Hackert T et al., 2016; Hackert T et al., 2017). These findings have been supported by subsequent multicenter studies, which also reported improved overall survival compared with conventional surgical approaches (Kandel P et al., 2018; Michelakos T et al., 2019).

In terms of morbidity, this technique does not appear to significantly increase major postoperative complications compared to standard surgery, although functional disorders related to denervation, particularly postoperative diarrhea, are commonly observed (Addeo P et al., 2020; Welsch T et al., 2011).

Furthermore, several studies suggest that this approach reduces the need for arterial resections without compromising oncological outcomes, representing a major advantage in terms of morbidity and mortality (Klompmaker S et al., 2018; Del Chiaro M et al., 2019).

5. Limitations and Controversies

Despite its promising results, the "Triangle Operation" raises several concerns. The main limitation lies in the difficulty of distinguishing post-treatment fibrosis from residual tumor, both preoperatively and intraoperatively, which may lead to incomplete resection (Katz MH et al., 2012).

Additionally, this technique is highly dependent on surgical expertise and requires advanced skills in vascular dissection, thereby limiting its application to high-volume specialized centers (Birkmeyer JD et al., 2002). The lack of standardization in both technique and indications further restricts its widespread adoption (Asbun HJ et al., 2014).

Finally, patient selection remains critical, as the "Triangle Operation" is primarily indicated in patients demonstrating a favorable response to neoadjuvant chemotherapy without disease progression (Tempero MA et al., 2021).

6. Discussion

The "Triangle Operation" represents a major paradigm shift in pancreatic surgery, moving from a purely anatomical approach toward a strategy focused on controlling the tumor microenvironment. It is based on the concept that peri-arterial structures serve as a sanctuary for tumor dissemination and must therefore be systematically resected to improve oncological outcomes (Strobel O et al., 2019; Neoptolemos JP et al., 2018).

This approach is closely linked to advances in medical oncology, particularly neoadjuvant chemotherapy, which enables better patient selection for radical surgery (Sohal DPS et al., 2021; Menoura R et al., 2025). It is thus part of a comprehensive multimodal strategy combining systemic therapy and targeted surgical intervention.

7. Conclusion

The "Triangle Operation" constitutes a significant advancement in the surgical management of borderline

resectable and locally advanced pancreatic cancer. By enabling complete dissection of the peri-arterial compartment, it improves R0 resection rates while avoiding complex arterial reconstruction. However, its indication must remain cautious and restricted to carefully selected patients, and it should be performed in specialized centers with advanced expertise in pancreatic surgery.

References

Addeo P, Delpero JR, Paye F, Sauvanet A, Farges O, Bachellier P, et al. (2020). Postoperative outcomes. *Surgery*, *168*(1), 93–101.

Asbun HJ, Conlon K, Fernandez-Cruz L, Friess H, Shrikhande SV. (2014). International consensus on pancreatic surgery. *Ann Surg*., *259*(1), 3–17.

Bapat AA, Hostetter G, Von Hoff DD, Han H. (2011). Perineural invasion and associated pain in pancreatic cancer. *Cancer Res*., *71*(24), 7567–7572.

Birkmeyer JD, Siewers AE, Finlayson EV, Stukel TA, Lucas FL, Batista I, et al. (2002). Hospital volume and surgical mortality. *N Engl J Med*., *346*(15), 1128–1137.

Cassinotto C, Cortade J, Belleannée G, Lapuyade B, Terrebonne E, Vendrely V, et al. (2014). Imaging of pancreatic cancer after neoadjuvant therapy. *Radiology*, *273*(1), 108–118.

Ceyhan GO, Schäfer KH, Kerscher AG, Rauch U, Demir IE, Kadihasanoglu M, et al. (2009). Nerve growth in pancreatic cancer. *Nat Rev Gastroenterol Hepatol*., *6*(11), 699–707.

Conroy T, Hammel P, Hebbar M, Ben Abdelghani M, Wei AC, Raoul JL, et al. (2018). FOLFIRINOX or gemcitabine as adjuvant therapy. *N Engl J Med*., *379*(25), 2395–2406.

Del Chiaro M, Rangelova E, Segersvärd R, Arnelo U. (2019). Management of locally advanced pancreatic cancer. *Br J Surg*., *106*(3), e42–e53.

Esposito I, Kleeff J, Bergmann F, Reiser C, Herpel E, Friess H, et al. (2008). Most pancreatic cancer resections are R1 resections. *Ann Surg*., *248*(5), 788–795.

Ferrone CR, Marchegiani G, Hong TS, Ryan DP, Deshpande V, McDonnell EI, et al. (2015). Radiological and pathological response after neoadjuvant therapy. *J Clin Oncol*., *33*(5), 515–522.

Hackert T, Sachsenmaier M, Hinz U, et al. (2017). Radical surgery for pancreatic cancer. *Ann Surg*., *266*(5), 787–794.

Hackert T, Sachsenmaier M, Hinz U, Schneider L, Michalski CW, Springfeld C, et al. (2016). Locally advanced pancreatic cancer: Neoadjuvant therapy and surgery. *Ann Surg*., *264*(3), 457–463.

Hackert T, Werner J, Büchler MW. (2018). Surgical techniques in pancreatic cancer. *HPB (Oxford)*, *20*(Suppl 1), S1–S6.

Hackert, T., Strobel, O., Michalski, C. W., et al. (2017). The TRIANGLE operation – radical surgery after neoadjuvant treatment for advanced pancreatic cancer. *HPB*, *19*(11), 1001–1007.

Hartwig W, Hackert T, Hinz U, Hassenpflug M, Strobel O, Büchler MW, et al. (2013). Pancreatic cancer surgery outcomes. *Surgery*, *153*(2), 161–170.

Inoue Y, Saiura A, Yoshioka R, Ono Y, Takahashi M, Arita J, et al. (2015). Artery-first approach. *Ann Surg*., *261*(6), 1092–1103.

Janssen QP, O'Reilly EM, van Eijck CHJ, Groot Koerkamp B. (2019). Neoadjuvant treatment in pancreatic cancer. *J Natl Cancer Inst*., *111*(8), 782–794.

Kandel P, Wallace MB, Stauffer JA, Raimondo M, Woodward TA, Gomez V, et al. (2018). Outcomes after neoadjuvant therapy. *HPB (Oxford)*, *20*(6), 507–515.

Katz MH, Pisters PW, Evans DB, Sun CC, Lee JE, Fleming JB, et al. (2012). Borderline resectable pancreatic cancer. *Ann Surg Oncol*., *19*(8), 2787–2795.

Klompmaker S, Peters NA, van Hilst J, Bassi C, Busch OR, Dervenis C, et al. (2018). Outcomes after vascular resections. *Ann Surg*., *267*(3), 547–556.

Liebig C, Ayala G, Wilks JA, Berger DH, Albo D. (2009). Perineural invasion is an independent prognostic factor. *Br J Cancer*, *101*(2), 349–356.

Menoura R, Tibermacine W, Nouar M, Achouri R, Bendridi M. (2025). The combined approach in cephalic duodenopancreatectomy: a surgical strategy adapted to complex forms. *J Oncol Res Case Rep.*, *2*(2). doi:10.1234/rpc.jorcr/0032

Michelakos T, Pergolini I, Castillo CF, Honselmann KC, Cai L, Deshpande V, et al. (2019). Predictors of

resectability. *Ann Surg*., *269*(4), 733–740.

Mollberg N, Rahbari NN, Koch M, Hartwig W, Hoeger Y, Büchler MW, et al. (2011). Arterial resection during pancreatectomy. *Ann Surg*., *254*(6), 882–893.

Nagakawa T, Konishi I, Ueno K, Ohta T, Kayahara M, Miyazaki I. (1996). Extended radical surgery. *Surgery*, *119*(5), 494–501.

Neoptolemos JP, Kleeff J, Michl P, Costello E, Greenhalf W, Palmer DH. (2018). Therapeutic developments. *Lancet*, *391*(10125), 1011–1024.

Pedrazzoli S, DiCarlo V, Dionigi R, Mosca F, Pederzoli P, Pasquali C, et al. (1998). Standard versus extended lymphadenectomy. *Ann Surg*, *228*(4), 508–517.

Siegel RL, Miller KD, Wagle NS, Jemal A. (2023). Cancer statistics. *CA Cancer J Clin*., *73*(1), 17–48.

Sohal DPS, Kennedy EB, Khorana A, Copur MS, Crane CH, Garrido-Laguna I, et al. (2021). Metastatic pancreatic cancer guidelines. *J Clin Oncol*., *39*(23), 2632–2648.

Strobel O, Hank T, Hinz U, Bergmann F, Schneider L, Springfeld C, et al. (2019). Pancreatic cancer surgery after neoadjuvant therapy. *Ann Surg*., *269*(2), 291–300.

Strobel O, Neoptolemos J, Jäger D, Büchler MW. (2019). Optimizing pancreatic cancer treatment. *Nat Rev Clin Oncol*., *16*(1), 11–26.

Suker M, Beumer BR, Sadot E, Marthey L, Faris JE, Mellon EA, et al. (2016). FOLFIRINOX for locally advanced pancreatic cancer: a systematic review. *Lancet Oncol*., *17*(6), 801–810.

Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. (2021). Global cancer statistics 2020: GLOBOCAN estimates. *CA Cancer J Clin*., *71*(3), 209–249.

Tempero MA, Malafa MP, Al-Hawary M, Behrman SW, Benson AB, Cardin DB, et al. (2021). NCCN guidelines pancreatic cancer. *J Natl Compr Canc Netw*., *19*(4), 439–457.

Truty MJ, Kendrick ML, Nagorney DM, Smoot RL, Cleary SP, Graham RP, et al. (2020). Factors predicting survival after resection. *J Am Coll Surg*., *230*(4), 491–503.

Verbeke CS, Leitch D, Menon KV, McMahon MJ, Guillou PJ, Anthoney A. (2006). Redefining resection margin status in pancreatic cancer. *Histopathology*, *48*(5), 522–530.

Welsch T, Kleeff J, Friess H, Büchler MW. (2011). Diarrhea after pancreatic surgery. *Surgery*, *149*(3), 310–316.