Wang et al.
European Journal of Medical Research (2025) 30:322
https://doi.org/10.1186/s40001-025-02593-5

European Journal of Medical Research

REVIEW

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Omentum transplantation for malignant tumors: a narrative review of emerging techniques and clinical applications

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Abstract

Omentum transplantation has emerged as a versatile and effective technique across various surgical disciplines due to its unique properties of immunological surveillance, anti-inflammatory effects, and wound healing promotion. In breast cancer surgeries, it has been utilized to manage locoregional issues and immediate reconstruction, providing satisfactory cosmetic outcomes and minimal complications, particularly in patients who had previously undergone irradiation. For esophageal cancer, omental reinforcement has significantly reduced anastomotic leak rates and post-operative complications, supporting its use in esophagectomy and complex cardiothoracic surgeries. In gynecological surgeries, the use of omental flaps has shown excellent results in neovaginal reconstruction following pelvic exenteration, offering distinct advantages over myocutaneous flaps by reducing morbidity and preserving sexual function. Additionally, omental transposition has proven beneficial in reducing surgical morbidity following radical abdominal hysterectomy and in managing vaginal cuff dehiscence through vaginal approaches. Robotic-assisted omental flap harvesting has enhanced precision and reduced complications in reconstructive surgeries, making it a promising minimally invasive approach in regenerative surgery and complex reconstructions, such as for facial skeleton reconstruction. The omentum has also been beneficial in laparoscopic procedures for pudendal nerve decompression and in managing thoracic aortic graft infections, demonstrating its versatility and effectiveness in various clinical settings. These studies collectively highlight the omentum's significant role in improving surgical outcomes, reducing complications, and enhancing the quality of life for patients, solidifying its place as a valuable tool in modern surgical practice. This article provides a comprehensive narrative review of omentum transplantation in oncology, discussing its current applications and future potential as a standard treatment modality.

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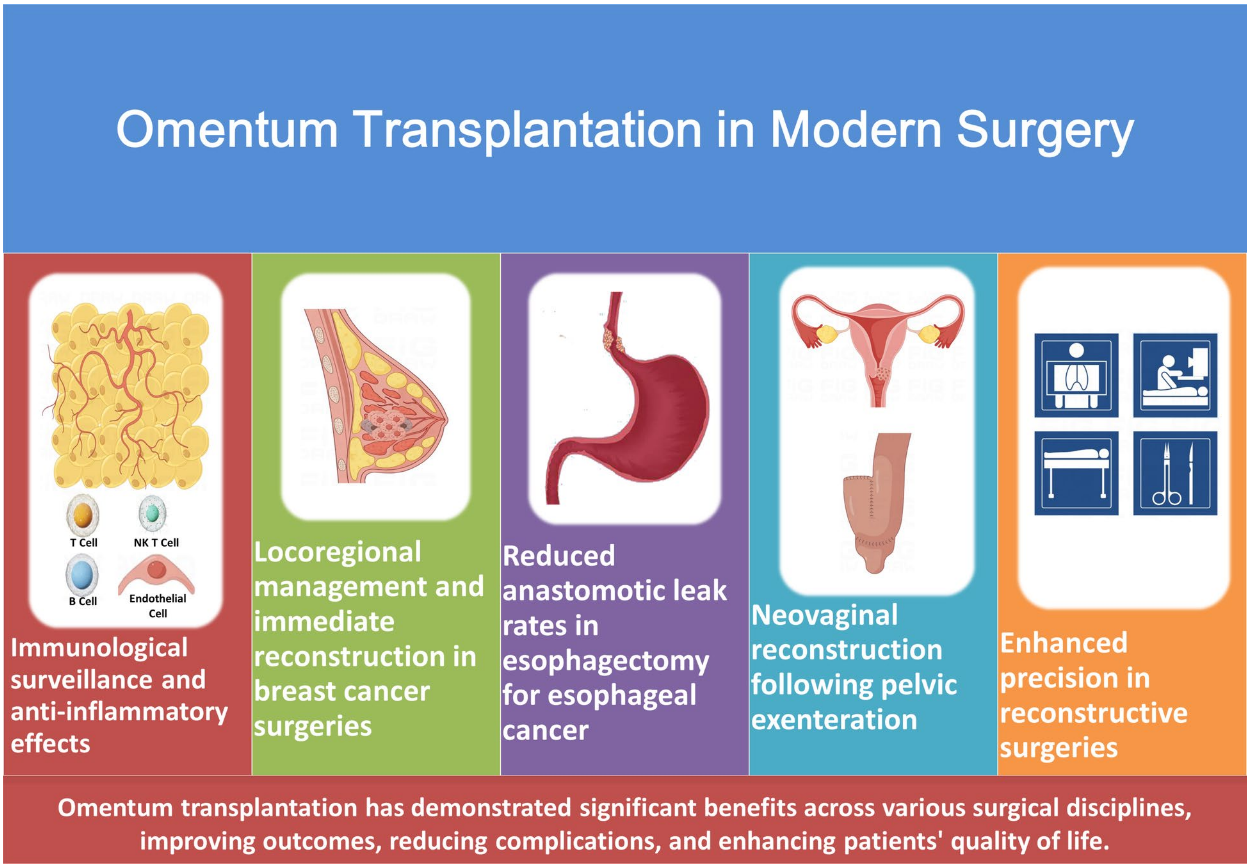
Graphical Abstract



Introduction

The omentum, a large fold of peritoneum that hangs down from the stomach, is often referred to as the "policeman of the abdomen" due to its rich supply of blood vessels, lymphatic tissue, and fat deposits. This unique anatomical structure plays a critical role in immune responses, wound healing, and tissue regeneration [1, 2]. In recent years, omentum transplantation surgery has emerged as a promising therapeutic approach in the treatment of malignant tumors.

The global incidence of malignant tumors continues to rise, with cancer remaining one of the leading causes of morbidity and mortality worldwide [3]. Traditional treatments, such as surgery, chemotherapy, and radiation therapy, often come with significant side effects and may not always be successful in preventing tumor recurrence and metastasis [4–6]. Therefore, there is an urgent need for alternative treatment modalities that can enhance the efficacy of existing therapies and improve patient outcomes.

Omentum transplantation surgery involves the transfer of the omentum to the tumor site or affected area, leveraging its immunomodulatory properties to inhibit tumor growth and spread. The omentum's ability to secrete various cytokines, growth factors, and immune cells makes it an ideal candidate for such procedures [7, 8]. Clinical studies have demonstrated the potential of omentum transplantation in various types of malignant tumors, including breast cancer, colorectal cancer, thyroid cancer, and cervical cancer [9–12].

Recent advancements in surgical techniques and a better understanding of the omentum's biological functions have further propelled the interest in this innovative approach. For instance, minimally invasive laparoscopic techniques have been developed to reduce the surgical risks associated with omentum transplantation [13]. Additionally, research into the omentum's role in immune modulation has opened new avenues for enhancing its therapeutic potential in cancer treatment [14].

This paper aims to provide a comprehensive overview of the progress made in omentum transplantation surgery for the treatment of malignant tumors. It will discuss the historical development and surgical techniques, applications in different malignancies, advantages, and challenges, as well as future directions and trends in this field. By examining the latest research and clinical data, this review seeks to highlight the significance of omentum transplantation surgery and its potential to become a standard treatment modality in oncology.

Overview of omentum transplantation surgery

Omentum transplantation surgery involves the mobilization and transplantation of the omentum, a fatty apron-like structure in the abdominal cavity, to different anatomical sites. This procedure leverages the omentum's unique properties, including its rich vascular network, immune cell population, and regenerative capabilities, to aid in the treatment of various medical conditions, particularly malignant tumors. In this section, we will provide a comprehensive overview of the surgical techniques, indications, and clinical applications of omentum transplantation, highlighting its role in modern surgical practice and its potential benefits for patients with cancer.

Definition and basic principles

Omentum transplantation surgery involves the surgical transfer of the omentum, a large, fatty, and vascularized structure within the abdomen, to another site in the body. This procedure leverages the omentum's unique properties, including its rich supply of blood vessels, lymphatic tissue, and immunological functions, to aid in the treatment of various conditions, particularly malignant tumors. The basic principles of omentum transplantation include:

Modulating local immune response

The omentum's immunological activity helps in creating a localized immune environment that can target tumor cells more effectively. Along with its milky spots (MS), omentum contains a variety of unique immune cell populations, including regulatory T cells (Tregs), innate lymphoid cells (ILC2), natural killer T cells (NKT), and macrophages. These cells are believed to play a crucial role in modulating local immune responses, potentially by dampening inflammatory reactions. B1 cells in the omentum are particularly poised to respond to bacterial antigens, promote mucosal immunity in the gut, and produce IL-10, contributing to the anti-inflammatory and possibly tolerogenic environment of the omentum [15].

While visceral adipose tissue (VAT)-associated Tregs are mainly studied in large fat depots like epididymal fat, which lack MS, they are also found in the omentum, where they likely help regulate local immune responses [16]. Obesity is associated with a reduction in VAT-associated Tregs in epididymal fat, alongside an increase in inflammatory cells and cytokines. Although the role of NKT cells in the omentum was not specifically tested in metabolic studies, their prevalence in this tissue suggests they significantly influence local immune reactions, such as the expansion of fat-associated lymphoid clusters (FALCs) in response to inflammatory stimuli [17].

In summary, previous studies highlight the critical role of various immune cells in the omentum in modulating local immune responses, particularly in suppressing inflammation and maintaining immune homeostasis. They also point to the impact of obesity on the distribution and function of these immune cells, as well as the complex regulatory mechanisms within the omentum's immune environment.

Promoting wound healing and angiogenesis

The omentum is a highly vascularized fatty connective tissue, typically around 25×35 cm in size, though its volume can vary significantly among individuals. Its unique structure and rich vascular supply give it a high capacity for absorption, pronounced angiogenic activity, innate immune function, and the ability to adhere to local structures. These properties make it suitable for various medical applications, including promoting hemostasis and supporting ischemic tissues.

Bhar et al. developed a biomimetic hydro scaffold using omentum tissue-derived decellularized extracellular matrix (dECM) and silk fibroin (SF) proteins. This hydroscaffold mimics the provisional skin tissue matrix by combining the behavior of a collagenous fibrous scaffold with a hydrogel. It offers a promising, cost-effective wound dressing solution for chronic diabetic wounds, requiring only a single topical administration [18].

Costa et al. studied the mechanism behind the volume increase of laparoscopically harvested omentum flaps used for treating breast deformities. They found significant increases in adipocyte size and microvascular density, suggesting that neoangiogenesis was stimulated by an initial increase in VEGF expression. Although VEGF levels decreased over time, the initial surge likely caused adipocyte hypertrophy and increased vascularization, contributing to the observed volume increase [19].

Li et al. explored the effects of activated omentum-conditioned medium (aOCM) on diabetic wound healing. They observed that aOCM significantly accelerated wound repair, enhancing epidermal and collagen deposition by day 9. Additionally, aOCM promoted neovascularization and peripheral nerve regeneration, showing potential as a new therapy for diabetic wounds by positively influencing the wound-healing process in a diabetic mouse model [20].

In summary, these studies highlight the omentum's versatile applications in medical treatments due to its unique properties. The development of innovative therapies, such as biomimetic hydroscaffolds and aOCM, underscores the omentum's potential in improving wound healing and reconstructive surgery outcomes.

Providing a biological scaffold

The omentum can serve as a biological scaffold, supporting tissue regeneration and repair. Gama et al. demonstrated the omentum's significant role in the mdx mouse, a model for Duchenne muscular dystrophy (DMD). They found that the omentum in these mice is rich in milky spots and produces growth factors that promote diaphragm muscle regeneration, suggesting it could be a therapeutic target for DMD [21]. In 2022, Tayfun et al. investigated the effect of autologous omentum flaps on injured renal tissues in rats. Their results indicated that using omental tissue for kidney repair reduced inflammation and granulation compared to primary repair, suggesting a more effective healing process with less fibrosis and functional loss [22]. In a pilot study by Atala et al., a cell-seeded composite collagen polyglycolic acid covered with greater omentum was used to reconstruct a patient's bladder [23]. While initial results showed improved urodynamics and minimal adverse events after six months, a longer-term study by Joseph et al. revealed serious adverse events like bladder rupture and bowel obstruction [24]. These issues were attributed to scar formation and bladder hardening in the reconstructed bladder. In 2023, Nguyen et al. developed the omental fat-augmented free flap (O-FAFF) as an alternative for breast reconstruction. In result, the O-FAFF is ideally suited for women of lower BMI and could dramatically increase the number of women who are candidates for autologous breast reconstruction [25]. Future research should focus on understanding the mechanisms behind these complications and developing strategies to enhance the safety and efficacy of omentum-based therapies. This approach could unlock new therapeutic possibilities while ensuring patient safety and optimal outcomes.

Relieving the lymphedema

Lymphedema, a common postoperative complication, frequently occurs in patients who have undergone lymphadenectomy due to cancer. Common treatment methods include compression bandaging of the affected limb and artificial lymphatic bypass drainage. While these therapies can help control the progression of lymphedema, they do not provide a complete cure for this persistent condition. Moreover, as lymphedema is an immune-mediated fibrotic disease, stagnant lymph fluid triggers an inflammatory response that leads to lymphatic fibrosis, further exacerbating lymphatic stasis. This vicious cycle results in the progressive worsening of lymphedema [26]. Therefore, vascularized lymph node transfer (VLNT), including omentum transplantation, has been employed to restore immunologically active lymph nodes and provide an outlet for lymphatic drainage.

In 2022, Lee et al. introduced a novel flowthrough configuration for omental VLNT in the popliteal space. The procedure involved debulking the medial popliteal fat pad and gastrocnemius muscle, followed by venous and arterial anastomoses using the gastroepiploic and medial sural vessels. A retrospective review of six patients with chronic lower extremity lymphedema (June 2019–November 2020) showed no postoperative complications in five patients who completed at least three months of follow-up. The study highlights the medial sural vessels as optimal recipients for the flowthrough omental flap [27]. Brown et al. conducted a prospective study evaluating the safety and efficacy of VLNT using multiple outcome measures. Among 89 patients, donor sites included the omentum (73%), axilla (13%), supraclavicular (7%), and groin (3.5%), with a mean follow-up of 23.7 months. At two years post-op, all metrics showed significant improvement: lymphedema life impact scale (28.4%), limb volume reduction (20%), bioimpedance (27.5%), cellulitis reduction (93%), and 34% no longer needing compression. Complications were minimal, with no donor site lymphedema. Omentum, posing no donor site risk, is an optimal choice for VLNT [28]. In 2024, Tian et al. used the omentum to treat chronic ulceration from lymphatic fluid leakage. After successful revascularization, no leakage, inguinal wounds, or lymphatic exudate were observed, and lower limb lymphedema improved. This approach shows promise for managing refractory wounds from lymphatic fistulas [29]. Recent studies suggest that using free omental flaps for lymphatic reconstruction and lymphedema treatment is both safe and effective. However, future research should focus on elucidating the molecular mechanisms underlying its therapeutic effects to further validate its efficacy. Additionally, current studies are largely limited to case reports or small-scale studies. Large, multicenter trials are needed to provide more robust evidence and solidify the role of omental transplantation in lymphedema treatment.

Historical development

The concept of omentum transplantation dates back to the late nineteenth century, with early applications primarily focused on treating infections and aiding in wound healing. Over time, the surgical techniques and understanding of the omentum's biological properties have evolved, leading to broader applications, including the treatment of malignant tumors. From all the evidence and considerations that have now been adduced, the protective function of the omentum in penetrating abdominal wounds, and to a more limited extent in intestinal lesions, has been fully established (Table 1).

Early applications

The initial uses of omentum transplantation were mainly for treating chronic infections and aiding wound healing, leveraging the omentum's natural healing and infection-combatting properties. In 1866, Kenneth et al. reported eight cases demonstrating that the omentum could act as a plug-in for small penetrating abdominal wounds, preventing the protrusion of other viscera [30]. Nicholas Senn was the first to advocate using an omental graft to prevent leakage from intestinal anastomosis sites, observing that these grafts became firmly adherent to the intestine within 12 to 18 h and were well-supplied with blood vessels within 18 to 48 h [31]. Subsequently, others have reported the use of free or pedicled omental grafts in intestinal anastomoses, gastrointestinal tract perforations, and covering denuded peritoneal surfaces [32].

These early applications laid the groundwork for the diverse uses of omentum transplantation in modern medicine. The ability of omental grafts to adhere quickly and establish a blood supply makes them invaluable in various surgical contexts, including gastrointestinal and peritoneal surgeries. However, while the historical data demonstrate the omentum's potential, it is essential to integrate these insights with contemporary surgical techniques and knowledge to optimize outcomes.

Mid-twentieth century

Advances in transparent chamber techniques and an improved understanding of the omentum's vascular properties have broadened its application to include complex microscopic surgeries. One of the early uses was in establishing autografts in rabbits' ears, where omentum grafting stimulated endothelial growth both intrinsic to the grafts and in the vessels upon which the grafts were placed [33]. Pettet et al. conducted an experimental study to investigate the biological fate of free omental grafts when placed around the suture line of an end-to-end anastomosis of the colon. They found that free omental grafts should not be used to reinforce intestinal anastomoses within the peritoneal cavity due to the risk of intestinal obstruction from intraperitoneal adhesions [32]. However, these grafts might be beneficial in extraperitoneal anastomoses.

Late twentieth century to present

Research into the omentum's role in cancer biology led to its application in oncological surgeries. Innovations in minimally invasive surgery further enhanced the feasibility and safety of omentum transplantation procedures. Breton et al.'s research emphasizes the practical

Table 1 Historical development of omental transplantation

Period	Studies (Year)	Detalis and Fingdings
Late 19 th Century	Kenneth et al. (1877) [30]	The omentum could act as a plug in small penetrating abdominal wounds, preventing the protrusion of other viscera
	Senn et al. (1888) [31]	Omental graft can be firmly adherent to the intestine within 12 to 18 h and well-supplied with blood vessels within 18 to 48 h
Mid-20 th Century	Williams et al. (1953) [33]	Omentum grafting stimulated endothelial growth both intrinsic to the grafts and in the vessels upon which the grafts were placed
	Pettet et al. (1956) [32]	The free or pedicled omental grafts can be used in intestinal anastomoses, gastrointestinal tract perforations, and covering denuded peritoneal surfaces
Late 20 th Century to Present	Breton et al. (1990) [34]	The research emphasizes the practical benefits of omental flaps, such as high plasticity and reduced morbidity, while also noting significant drawbacks like excessive mucus production and the requirement for abdominal surgery
	Carlson et al. (1997) [35]	The gastro-omental flap for pharyngeal reconstruction after extensive radiation highlights the flap's versatility and potential as a secondary option in complex cases
	Cheung et al. (1997) [36]	The omental transposition for breast cancer recurrence underscores the procedure's viability but may not provide long-term solutions for all patients
	Patel et al. (2009) [37]	The gastro-omental flap provides a viable option in high-risk patients undergoing circumferential pharyngeal reconstruction
	Vidhyadharan et al. (2018) [38]	1. Speech and swallowing were good, especially after partial glossectomy 2. Gastric mucosal flaps tolerated radiation well
	Righini et al. (2021) [39]	The GOFF can restore digestive continuity and reconstruct neck skin in cases of large hypopharyngeal tumors, making it a reliable and robust option, particularly in challenging conditions

benefits of omental flaps, such as high plasticity and reduced morbidity, while also noting significant drawbacks like excessive mucus production and the requirement for abdominal surgery. This indicates that while omental flaps have promising applications, they also come with notable risks that need to be managed [34]. Carlson et al.'s study on the gastro-omental flap for pharyngeal reconstruction after extensive radiation highlights the flap's versatility and potential as a secondary option in complex cases. This is particularly valuable for patients with limited local flap options, demonstrating the adaptability of the omentum in complex reconstructive scenarios [35]. Cheung et al.'s report on omental transposition for breast cancer recurrence underscores the procedure's viability but also its limitations in terms of long-term local control and patient survival. The high rate of new recurrences and the short median period of local control indicate that while the technique is safe, it may not provide long-term solutions for all patients [36]. Patel et al. reviewed gastro-omental free flap (GOFF) use in 11 pharynx laryngectomy patients, achieving a 91% oral diet success and functional speech in all suitable patients, despite a 54% morbidity rate [37]. Vidhyadharan et al. reported on 9 glossectomy patients, highlighting GOFF's benefits in post-radiotherapy saliva-depleted cases and minimal donor site morbidity [38]. Righini et al. emphasized GOFF's reliability in hypopharyngeal reconstruction, restoring digestive continuity, and neck skin in complex tumor cases [39]. Overall, these studies collectively underscore the importance of careful patient selection and thorough evaluation of potential risks and benefits when considering omental flaps for reconstructive surgery.

Surgical techniques

Omentum transplantation surgery involves a series of intricate and highly specialized surgical techniques designed to mobilize and transplant the omentum to various anatomical sites. These techniques have evolved significantly over the years, driven by advances in surgical technology and a deeper understanding of the omentum's unique properties. This section provides a detailed overview of the current surgical approaches employed in omentum transplantation, including traditional open surgery, minimally invasive techniques, and emerging robotic-assisted procedures.

Open surgery

This traditional approach involves a large abdominal incision to access and mobilize the omentum. It is typically used in complex cases where extensive exposure is required. Lots of cases are associated with thoracic surgery. Jurkiewicz et al. demonstrated its reliability and long-term success in reconstructive procedures, while Colen et al. highlighted its utility in managing acute mediastinitis following cardiopulmonary surgeries [40, 41]. These findings reinforce the role of the omentum as a valuable tool in complex reconstructive surgeries, providing excellent vascularized coverage and supporting tissue healing with minimal complications.

Laparoscopic surgery

Minimally invasive techniques have become increasingly popular due to their reduced postoperative pain, shorter hospital stays, and quicker recovery times. Laparoscopic omentum transplantation involves several small incisions through which specialized instruments and a camera are inserted to perform the surgery. Previous studies have demonstrated the diverse and promising applications of omentum transplantation in various medical fields. Erdogru et al. showed that laparoscopic pudendal nerve decompression combined with omental flap transposition is a feasible and minimally invasive approach with potential for treating intractable genitourinary problems [42]. Zhou et al. found that laparoscopic omental transposition effectively controlled thoracic aortic graft infections, suggesting it is a less invasive alternative to graft replacement [43]. Komono et al. reported the successful use of an omental flap combined with negative pressure wound therapy (NPWT) in preventing infection and reconstructing large pelvic defects after total pelvic exenteration for anal fistula cancer, indicating its potential as a new option for complex surgical reconstructions [44]. These studies collectively highlight the versatility and efficacy of omental transplantation in enhancing surgical outcomes and expanding treatment possibilities.

Robotic-assisted surgery

This advanced technique combines the benefits of minimally invasive surgery with enhanced precision and control. Robotic systems allow for greater dexterity and accuracy, making it possible to perform complex omentum transplantation procedures with improved outcomes. Recent studies highlight the advancements and benefits of robotic technology in omentum transplantation and reconstructive surgery. In 2019, Ozkan successfully performed robotic harvesting of a free omental flap, resulting in an uneventful recovery and discharge on the 12 th day postoperatively [45]. Naujokat et al. demonstrated the potential of robot-assisted scaffold implantation in the greater omentum for facial skeleton reconstruction, achieving successful bone formation with minimal invasiveness using the da Vinci Xi surgical system [46]. Arif et al.'s review of 16 studies involving 128 patients found that robotic-assisted free flap harvests, predominantly for breast reconstruction, yielded a 99%

flap success rate with minimal complications [47]. These findings underscore the promise of robotic techniques in enhancing precision, reducing recovery times, and improving clinical outcomes in complex reconstructive procedures.

Steps involved in omentum transplantation surgery

The process of omentum transplantation surgery is a multi-step procedure that requires meticulous planning and execution to ensure successful outcomes. Each step is critical, from the initial patient evaluation and preoperative preparations to the precise dissection and transplantation of the omentum, followed by careful postoperative care. This section outlines the key steps involved in omentum transplantation surgery, providing detailed descriptions of the techniques and considerations at each stage [9, 48].

Patient preparation

Preoperative assessment and planning are crucial to determine the suitability of omentum transplantation for the patient. This includes imaging studies, laboratory tests, and a thorough evaluation of the patient's overall health.

Omentum mobilization

The omentum is carefully dissected and mobilized from its attachments to the stomach and transverse colon. Care is taken to preserve its blood supply.

Transplantation

The mobilized omentum is then transferred to the target site, which could be the site of a tumor resection or a defect requiring reconstruction. The omentum is secured in place, ensuring adequate blood flow.

Closure and recovery

The surgical site is closed, and the patient is monitored during the recovery period. Postoperative care includes pain management, monitoring for complications, and ensuring proper wound healing.

Applications in malignant tumor treatment

The application of omentum transplantation in the treatment of malignant tumors has garnered significant interest due to the omentum's unique immunological and regenerative properties. By leveraging these properties, omentum transplantation offers a novel approach to enhancing immune responses, promoting tissue healing, and delivering therapeutic agents directly to tumor sites. This section explores the various ways in which omentum transplantation is being utilized in the treatment of different types of malignant tumors, highlighting clinical evidence, specific cancer types, and the underlying mechanisms that make this approach promising for oncological surgery.

Immunological functions of the omentum

The omentum is known for its immunological properties, which play a critical role in its application in malignant tumor treatment. The omentum contains milky spots, which are clusters of immune cells, including macrophages, B cells, and T cells. These structures are involved in immune surveillance and response, making the omentum a unique and valuable tool in combating cancer.

Immune surveillance

The omentum plays a vital role in immunosurveillance through its unique structures and cell populations. Milky spots, specific to the omentum, house a variety of immune cells, including macrophages, lymphocytes, and natural killer (NK) cells, which can detect and respond to foreign particles and pathogens. Macrophages in the omentum clear pathogens and debris, while B1 cells produce natural antibodies and anti-inflammatory cytokines like IL-10. Regulatory T cells (Tregs) help maintain immune tolerance and prevent excessive inflammation. NK cells target and destroy virus-infected and tumor cells, and dendritic cells capture and present antigens to T cells, bridging innate and adaptive immunity. The omentum's ability to mobilize immune cells quickly in response to infection or injury underscores its role in controlling inflammation and promoting tissue repair. These coordinated actions make the omentum a key player in maintaining immune homeostasis and highlight its potential in therapeutic applications.

Anti-inflammatory and healing properties

Omentum transplantation aids in anti-inflammation and wound healing through multiple mechanisms. It secretes anti-inflammatory cytokines (e.g., IL-10, TGF-β) and adipokines (e.g., adiponectin) that reduce inflammation and promote tissue repair [49]. Omental macrophages switch to an anti-inflammatory phenotype, while the omentum's rich supply of vascular endothelial growth factor VEGF fosters angiogenesis, improving blood flow to the injured area [50]. The omentum also contains mesenchymal stem cells (MSCs) that differentiate into necessary cell types, aiding in tissue regeneration. Its extracellular matrix (ECM) components support structural integrity and cell migration, essential for wound closure [51, 52]. Tregs modulate immune responses to prevent excessive inflammation, and the omentum's natural debridement ability helps control infection by isolating and removing necrotic tissue [53]. Together, these mechanisms create an optimal environment for healing and regeneration, underscoring the therapeutic potential of omental transplantation.

Application in different types of malignancies

Omentum transplantation has shown promise in the treatment of various types of malignancies due to its unique immunological and regenerative properties. This section explores how omentum transplantation is being applied across different types of cancers, such as gastric, colorectal, ovarian, and pancreatic cancers. By examining specific case studies, clinical trials, and the underlying mechanisms that make the omentum an effective tool in combating these malignancies, we aim to highlight its potential benefits and the current state of research. Understanding these applications provides valuable insights into the versatility and adaptability of omentum transplantation in oncological surgery (Table 2). Here are some specific applications:

Gastric cancer

Gastric cancer, one of the most common and lethal malignancies worldwide, often requires extensive surgical resection. Omentum transplantation can aid in reconstructing the surgical site, promoting healing, and potentially enhancing the immune response against residual tumor cells. Long-term outcomes of laparoscopic gastrectomy have shown that omental transplantation can improve survival rates in gastric cancer patients though there is little evidence associated with the reports of omental transplantation in gastrectomy for gastric cancer [54]. Besides, traditional radical gastrectomy for gastric cancer often involves the prophylactic removal of the omentum to eliminate potential metastases. As gastric cancer research has progressed, the extent of radical gastrectomy has evolved, initially expanding and then reducing, to optimize surgical outcomes without compromising patient survival. The Japan Clinical Oncology Group (JCOG) has conducted several phase III

Table 2 Applications of omental transplantation in different malignancies

Types of malignancies	Studies (Year)	Details and findings
Gastric Cancer	Hirofumi et al. (2015) [54]	Omental transplantation can improve survival rates in gastric cancer patients
Colorectal Cancer	Hultman et al. (2010) [59]	Omental flaps can be used in reconstructing complex perineal defects after abdominoperineal resection or pelvic exenteration for anorectal malignancy, which significantly reduces postoperative complications
	Qin et al. (2021) [60]	Mesorectal reconstruction with a greater omental pedicle flap after total mesorectal excision for low rectal cancer patients greatly reduced low anterior resection syndrome and improved postoperative anal and rectal function, restoring patients' quality of life
	Liao et al. (2023) [10]	Greater omental transplantationcan facilitate faster and better recovery for low anterior resection syndrome
Breast Cancer	Williams et al. (1989) [62]	Patients with breast cancer treated with omental transposition can achieve worthwhile local control and symptom relief
	Li et al. (2017) [63]	Immediate breast reconstruction using omental flaps in reduced satisfactory cosmetic outcomes and minimal complications
	Nguyen et al. (2022) [64]	The novel technique using omental fat-augmented free flap for breast reconstruction resulted in stable breast volume and no postoperative complications
Esophageal Cancer	Shrager et al. (2003) [65]	The use of omental transposition in esophageal reconstruction can achieve rare complications
	Sepesi et al. (2012) [66]	Utilization of -omental free flap significantly reduced the anastomotic leak rate from 10.5% to 4.7%
	Ye et al. (2016) [67]	Mediastinal transposition of the omentum decreased postoperative intrathoracic infection rates and associated pharmacy costs for Ivor-Lewis esophagectomy
Head and Neck Cancer	Chahine et al. (2009) [69]	The gastro-omental free flap is characterised by multiple survival advantages that favour its use in the presence of inhospitable recipient site conditions
	Craig et al. (2017) [70]	Laparoscopic harvest of the gastro-omental free flap can negate some of the risks associated with open surgery
	Komanduri et al. (2021) [71]	Gastro-omental flap has the potential to provide mucosal cover, variable bulk from omen tum, soft and pliable tissue that can mould to the defect con tour and can retain mucus secretion even after radiation to facilitate oral lubrication
Cervical Cancer	Kusiak et al. (1996) [72]	Omental cylinder flap lined with a split-thickness skin graft for neovaginal reconstruction achieved viability without complications and retaining sexual function in 80% of patients
	Patsner et al. (1997) [73]	Patients who received an omental J-flap after radical abdominal hysterectomy had no complications even with postoperative radiation therapy
	Naruducci et al. (2003) [74]	Omental flap can be wused in repairing vaginal cuff dehiscence with bowel evisceration effectively via combined laparoscopic and vaginal approach

randomized controlled trials to assess the risks and benefits of surgical procedures. The JCOG9501 trial found no advantage in prophylactic para-aortic lymph node dissection over conventional D2 lymphadenectomy for advanced gastric cancer [55]. The JCOG0110 trial did not support prophylactic splenectomy during total gastrectomy for proximal gastric cancer without greater curvature involvement [56]. The JCOG1001 trial negated the value of omental bursa resection in gastric cancer surgery [57]. In a word, increasing evidence suggests that prophylactic omentectomy does not improve survival rates and may increase surgical risks and postoperative complications, which could highlight the utilization of omental transplantation for gastric cancer patients.

Colorectal cancer

In colorectal cancer, especially in advanced stages with peritoneal metastasis, the omentum can be used to deliver immune cells and therapeutic agents directly to the tumor site. This localized approach can help in controlling tumor growth and preventing further spread [58]. Given that most colorectal surgeries cause large defects in pelvic floor tissues, omentum repair can be a potentially valuable surgical modality. Hultman et al. demonstrated that using omental flaps in reconstructing complex perineal defects after abdominoperineal resection or pelvic exenteration for anorectal malignancy significantly reduces postoperative complications compared to reconstruction without omental flaps [59]. Similarly, Qin et al. showed that mesorectal reconstruction with a greater omental pedicle flap after total mesorectal excision (TME) for low rectal cancer patients greatly reduced low anterior resection syndrome (LARS) and improved postoperative anal and rectal function, restoring patients' quality of life [60]. Liao et al. supported these findings, highlighting the effectiveness of pedicled greater omental transplantation (PGOT) in alleviating LARS after total intersphincteric resection (ISR) in ultra-low rectal cancer patients, suggesting that PGOT can facilitate faster and better recovery [10]. As the studies indicate, incorporating the omentum in surgical reconstruction can lead to better functional recovery and quality of life for patients, making it a promising approach for broader clinical application.

Ovarian cancer

Ovarian cancer often spreads within the peritoneal cavity, making it challenging to treat. The omentum's immune-enhancing properties can be harnessed to improve the effectiveness of surgical debulking and chemotherapy. Research indicates that omentum transplantation may enhance the local immune environment and reduce tumor recurrence [61]. However, the metastasis of ovarian cancer is characterized by extensive intraperitoneal dissemination, which hinders the use of omentum flaps to repair defects in the pelvic floor and other parts after tumor cytoreductive surgery.

Breast cancer

Omentum transplantation has found significant applications in the context of breast cancer surgery, particularly following mastectomy and reconstructive procedures. The unique properties of the omentum, including its rich vascular supply, immune function, and angiogenic capabilities, make it a valuable tool for enhancing wound healing, reducing complications, and improving aesthetic outcomes in breast reconstruction. Williams et al. analyzed 43 patients with breast cancer treated with omental transposition for locoregional issues, achieving worthwhile local control and symptom relief in most cases, though recurrence occurred in some patients [62]. Li et al. reported immediate breast reconstruction using omental flaps in 10 patients, noting satisfactory cosmetic outcomes and minimal complications [63]. Nguyen et al. introduced a novel technique using an omental fat-augmented free flap for breast reconstruction in patients unsuitable for traditional methods, resulting in stable breast volume and no postoperative complications [64].

Esophageal cancer

Omentum transplantation has proven to be a valuable technique in the surgical treatment and reconstruction following esophageal cancer surgery. The unique properties of the omentum, including its rich vascular supply, immune function, and angiogenic capabilities, make it an effective tool for enhancing wound healing, reducing complications, and improving surgical outcomes in esophageal reconstruction. Shrager et al. reviewed the use of omental transposition in 85 complex cardiothoracic surgical cases, achieving an 88% success rate in addressing these issues, with rare complications [65]. Sepesi et al. studied 607 esophagectomy patients and found that using omentum significantly reduced the anastomotic leak rate from 10.5% to 4.7%, with omental reinforcement being a key factor in lowering leak rates and the need for reoperation [66]. Ye et al. retrospectively reviewed 208 Ivor-Lewis esophagectomy cases and found that mediastinal transposition of the omentum decreased postoperative intrathoracic infection rates and associated pharmacy costs [67]. The studies demonstrate that omental transposition is highly effective in reducing complications in complex cardiothoracic and esophageal surgeries. These findings support the broader application of omental transposition techniques to improve surgical outcomes and patient recovery.

Head and neck cancer

Omentum transplantation, also known as omentoplasty, has found applications in the surgical treatment of head and neck cancer, particularly in complex reconstructive procedures following extensive resection. The unique properties of the omentum, including its rich vascular supply, immune function, and angiogenic capabilities, make it an effective tool in enhancing wound healing, reducing complications, and improving surgical outcomes in thyroid cancer surgery. The use of omental flaps in the studies by Muehrcke et al. and Spaggiari et al. demonstrates their effectiveness in promoting tissue healing and restoring function in irradiated and complex surgical cases [11, 68]. Chahine et al. reviewed GOFF use for pharyngeal reconstruction in challenging cases, noting partial flap necrosis in 13% and fistula/flap stenosis in 27% of 15 patients [69]. Craig et al. described laparoscopic GOFF harvest for head and neck cancer reconstruction, reducing open surgery risks [70]. Komanduri et al. reported 100% flap survival in nine oral cavity reconstructions, highlighting GOFF's advantages like long pedicle length, rich vascular network, and low donor site morbidity, making it a reliable oral reconstruction option [71]. These findings underscore the value of omental transposition in enhancing blood supply and fibroplasia, making it a crucial technique for managing complications and ensuring successful outcomes in challenging surgical scenarios.

Cervical cancer

Omentum transplantation has emerged as a valuable technique in the reconstruction of the pelvic floor following pelvic exenteration in cervical cancer patients. This complex surgical procedure often leaves extensive defects that require robust and reliable tissue coverage to support healing, reduce complications, and improve patient outcomes. Kusiak et al. detailed their experience with 20 patients undergoing radical pelvic exenteration for gynecological malignancies, using an omental cylinder flap lined with a split-thickness skin graft for neovaginal reconstruction, achieving viability without complications and retaining sexual function in 80% of patients [72]. Partner et al. reported on 140 patients who received an omental J-flap after radical abdominal hysterectomy, resulting in no complications even with postoperative radiation therapy, highlighting the technique's efficacy in minimizing surgical morbidity [73]. Naruducci et al. described using a combined laparoscopic and vaginal approach with an omental flap to effectively repair vaginal cuff dehiscence with bowel evisceration, demonstrating the utility of laparoscopy for thorough inspection and precise flap positioning [74]. Despite all these advantages, surgeons are still cautious when choosing pelvic exsection for patients with advanced cervical cancer, which indirectly affects the research progress of omentum transplantation in repairing pelvic defects. This includes some factors. For example, patients still do not see significant improvement in their quality of life after pelvic clearance. In addition, because the female pelvis is more susceptible to external microbial invasion, severe infections after omentum transplantation are relatively common, which will be an important problem to be solved urgently.

Future directions and trends

Omentum transplantation surgery has emerged as a promising technique in the treatment of malignant tumors, leveraging the unique properties of the omentum to enhance immune responses, promote healing, and improve the efficacy of cancer treatments. The procedure has shown significant benefits in various types of cancers, particularly those within the abdominal cavity, such as gastric, colorectal, and ovarian cancers. However, despite its potential advantages, omentum transplantation is a complex and resource-intensive procedure that comes with its own set of challenges, including surgical complexity, risk of complications, and the need for specialized expertise. As research continues to evolve, the long-term outcomes and broader applicability of this technique are being further explored, offering hope for improved cancer treatment strategies in the future.

Advancements in surgical techniques

Minimally invasive surgery

The continued development and refinement of minimally invasive surgical techniques, such as laparoscopic and robotic-assisted surgery, are likely to enhance the feasibility and safety of omentum transplantation. These advancements can reduce operative times, minimize postoperative pain, and shorten recovery periods, making the procedure more accessible to a broader range of patients [46, 75]. Tassi et al. reported successful treatment of a patient with mediastinitis following hysterectomy and prosthetic repair, using a laparoscopically-prepared omental flap to fill the gap after infected prosthesis removal. Adequate preoperative management and minimally invasive surgery were key to the patient's recovery [76]. Frey et al. demonstrated the efficacy of robotically assisted omental flap harvest for vascularized lymph node transfer, noting no major complications and significant improvement in patient outcomes. The approach provided enhanced intra-abdominal visibility and maneuverability [77]. Chen et al. described a minimally invasive carinal reconstruction using a laparoscopically harvested omental flap and bronchial flap, reducing the risk of airway anastomosis complications and proving safe post-neoadjuvant treatment [78]. These studies collectively highlight the versatility and effectiveness of omental flap techniques in complex and minimally invasive surgeries, improving patient outcomes and reducing complications.

Precision surgery

The integration of advanced imaging technologies and intraoperative navigation systems can improve the precision of omentum transplantation. Enhanced imaging allows for better visualization of the omentum and target sites, facilitating more accurate dissection and placement, and potentially improving surgical outcomes [79]. Zhang et al. demonstrated that using the three-dimensional visualization technique (3DVT) in endoscopic breast-conserving surgery (EBCS) with pedicled omentum improves surgical outcomes, including less bleeding, shorter operating times, and better cosmetic results compared to traditional methods [80]. Settembre et al. found that routine pre-operative angio-multidetector computed tomography (MDCT) effectively identifies the gastroepiploic artery (GOA) and its branches for lower limb revascularization [81]. Park et al. showed that near-infrared (NIR) imaging with indocyanine green (ICG) enhances vascular perfusion assessment in laparoscopically harvested omental flaps, ensuring graft viability and favorable cosmetic outcomes in breast reconstruction [82]. These studies underscore the benefits of advanced imaging techniques in improving precision and outcomes in reconstructive surgeries.

Integration with other therapies

Combination with chemotherapy and immunotherapy

Combining omentum transplantation with systemic therapies, such as chemotherapy and immunotherapy, could enhance the overall efficacy of cancer treatment. The omentum's ability to provide localized drug delivery and immune modulation makes it an attractive adjunct to these therapies, potentially improving patient outcomes [83].

Biomaterials and tissue engineering

The use of biomaterials and tissue engineering techniques to enhance omentum transplantation is an emerging area of research. By incorporating bioengineered scaffolds or growth factors, researchers aim to further improve the regenerative and therapeutic capabilities of the omentum [84]. In 2010, Rocco et al. successfully reconstructed an extensive anterolateral defect after sternocostal resection of chondrosarcoma using three metallic transverse plates and an omental flap, simplifying the process and allowing future recurrence options [85]. Momoh et al. described a case of an elderly patient with an anterior pelvic floor defect who underwent successful reconstruction using a combination of human acellular dermal matrix and an omental flap [86]. In 2019, Kim et al. developed an artificial esophagus to enhance mucosal and muscle regeneration via a two-layered tubular scaffold and mesenchymal stem cell-based bioreactor system, achieving over 80% mucosal regeneration without fistula formation [87]. This study highlighted a novel approach for circumferential esophageal reconstruction, showing significant integration and vascularization in the regenerated tissues.

Clinical trials and evidence-based practice

Large-scale clinical trials

To fully establish the benefits and limitations of omentum transplantation, large-scale, multicenter clinical trials are needed. These studies will provide robust data on the long-term outcomes, optimal patient selection criteria, and best practices for integrating omentum transplantation into standard cancer treatment protocols [88]. In 2011, Dai et al. conducted a prospective, randomized study on 291 esophageal carcinoma patients, comparing esophagogastrectomy with a pedicle omental flap (group A) versus a stapled technique (group B). Results showed that group A had significantly fewer anastomotic leaks (1% vs. 6%) and strictures (6% vs. 16%) compared to group B, indicating reduced morbidity and mortality with the omental flap technique [89]. In 2024, Khorami et al. evaluated a modified vaginal fistula repair technique without an omental flap on 52 women. The study found that the modified approach significantly reduced surgical duration and hospital stay, with no significant difference in success rates compared to the classic method. These studies highlight the effectiveness of omental flap use in reducing complications and improving outcomes in esophageal and vaginal reconstructive surgeries [90]. The omental flap technique in esophagogastrectomy significantly decreases anastomotic leaks and strictures, while a modified approach without an omental flap in vaginal fistula repair reduces surgical time and hospital stay, demonstrating comparable success rates.

Standardization of procedures

Developing standardized protocols for omentum transplantation, including guidelines for surgical techniques, patient selection, and postoperative care, can help ensure consistency and improve outcomes across different clinical settings [91].

Training and education

Surgeon training programs

As the demand for omentum transplantation grows, specialized training programs for surgeons will be essential. These programs should focus on the unique technical aspects of the procedure and the management of potential complications, ensuring that more surgeons are equipped to perform omentum transplantation safely and effectively [92].

Interdisciplinary collaboration

Fostering collaboration between surgeons, oncologists, immunologists, and researchers is crucial for advancing the field of omentum transplantation. Interdisciplinary teams can work together to explore new applications, develop innovative therapies, and translate research findings into clinical practice [93].

Conclusion

Omentum transplantation surgery represents a promising and innovative approach to the treatment of malignant tumors, leveraging the unique properties of the omentum to enhance immune responses, promote healing, and improve therapeutic outcomes. This procedure has demonstrated significant potential in various types of cancers, particularly those within the abdominal cavity. Despite the numerous advantages, such as enhanced immunological response, promotion of wound healing, and versatility in applications, omentum transplantation also poses challenges, including surgical complexity, risk of complications, and the need for specialized expertise.

Future directions in the field aim to address these challenges through advancements in surgical techniques, integration with other therapies, and a deeper understanding of the omentum's biological and immunological functions. Large-scale clinical trials and standardized protocols will be essential in establishing the long-term efficacy and safety of omentum transplantation, ultimately paving the way for its broader adoption in clinical practice.

As research continues to evolve, the collaboration between surgeons, oncologists, immunologists, and researchers will be crucial in unlocking the full potential of omentum transplantation. This interdisciplinary effort holds the promise of developing more effective, personalized cancer treatments, thereby improving the prognosis and quality of life for patients with malignant tumors.

Acknowledgements
The authors are grateful to Mr. Ruisheng Guan for his kind help with the preparation of this paper.

Author contributions
Xiangyu Wang conceived the idea for the review and coordinated the overall project. Hao Yu conducted the literature search. Yanlei Dong analyzed the data and drafted the manuscript. Wenli Xie critically revised the manuscript for important intellectual content and assisted in finalizing the draft. All authors reviewed and approved the final version of the manuscript.

Funding
This work was supported by the Natural Science Foundation of Shandong Province [Grant number ZR2022QH179] and The Development Foundation of the Second Hospital of Shandong University [Grant number 2022YP03].

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Our institution does not require ethical approval for review.

Consent for publication
Our institution does not require patients' approval for review.

Competing interests
The authors declare no competing interests.

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Received: 26 December 2024 Accepted: 14 April 2025
Published online: 23 April 2025

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