Surgical delay in abdominal based flap surgery: a scoping review

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Contributions: (I) Conception and design: WM Rozen; (II) Administrative support: WM Rozen, V Yogaraj, M Siddiqui, E Lok; (III) Provision of study materials or patients: None; (IV) Collection and assembly of data: V Yogaraj, M Siddiqui, E Lok; (V) Data analysis and interpretation: WM Rozen, V Yogaraj, M Siddiqui, E Lok; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Background: The abdominal donor site is the most common flap used for breast reconstruction, with flap necrosis a feared complication. The technique of surgical 'delay' involves the inducing of relative ischemia to promote neovascularisation, amongst other metabolic adaptations, and has been used to augment flap vascularity and reduce this complication. There is significant variability in the manner in which flap surgery and surgical delay may be performed, such as the vessels ligated, the presence and degree of flap elevation, and the decision to harvest muscle with the flap, amongst other factors. A formal review of techniques, however, has not yet been performed, and there is no consensus as to the optimal technique for surgical delay.

Methods: A scoping review of the current literature was undertaken to determine the optimal surgical delay technique in abdominal-based flap surgery. A literature search was conducted across PubMed, Embase, Cochrane, and Medline databases. Data regarding the type of flap surgery, delay techniques, and corresponding clinical outcomes was collected and categorised by technique type.

Results: Nine studies met the inclusion criteria and were included for review. Levels of evidence and rates of complications were compared. The range of surgical delay techniques reported in the literature was described. Surgical delay was found to reduce overall complication rates, and the available data suggests it may be particularly beneficial in high-risk patients.

Conclusions: The current data supports delay as a viable method for reducing rates of complications. Further studies and data are required to compare surgical delay techniques and determine the benefit delay may pose to patients with risk factors.

Keywords: Microsurgery; breast reconstruction; anatomy

Submitted Jan 17, 2023. Accepted for publication Aug 17, 2023. Published online Nov 06, 2023.
doi: 10.21037/atm-23-306
View this article at: https://dx.doi.org/10.21037/atm-23-306

Introduction

Among the most concerning complications for surgeons performing flap-based breast reconstruction is loss or necrosis of the flap, a complication noted to occur in up to 30% of standard flaps (1). Flap survivability, then, is key in autologous breast reconstruction; the ability for the tissue to "take" or successfully assimilate with the recipient site being largely affected by how robustly it is vascularised.

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Surgical delay is one such technique aimed to improve this, whereby relative ischemia is induced in tissue in order to induce neovascularization and improve vascularity. First applications of the delay phenomenon can be traced back to Renaissance surgeon Gaspar Tagliacozzi, who published results of his upper-arm flap vascular delays in 1597 (2). Further studies since then aimed to characterise the precise mechanisms by which surgical delay enhanced flap survivability. While these processes have remained largely unknown, strides have been made in the last few decades describing the biochemical adaptations induced from delay, such as the tissue's compensatory alteration in sympathetic tone, reduced energy requirements, and overall increased ischaemic tolerance of the tissue (2). Furthermore, improvement of flap vascularity in human subjects has been explored through use of computed tomographic angiography (CTA), detailing the dilation of flap arteries and recanalization of veins in response to surgical delay (3).

The vascular and metabolic benefit of surgical delay is particularly significant in increasing the chances of flap survival in patients whose risk factors (obesity, smoking, and advanced age) historically have resulted in higher complication (4-6). Considering the rising prevalence of obesity and ageing population commonly seen in the developed world (7), this method allows surgeons to capture an ever-growing demographic previously considered to be unsuitable surgical candidates.

There are many aspects for the surgeon to consider when deciding how to perform the autologous reconstruction. Transverse rectus abdominis muscle (TRAM) flaps involve the harvesting of abdominal tissue including the skin, fat, and a portion of the muscle. Such flaps involve the ligation of the deep or superficial inferior epigastric vessels and can either remain attached to their original blood supply (pedicled) or be removed completely and re-anastomosed with recipient-site vessels (free flap). Newer flaps include the deep inferior epigastric perforator (DIEP) flap, an abdominal-based free flap which does not harvest muscle (8-10). Such flaps may be more difficult to perform given the requirement for re-anastomoses but can preserve the patient's abdominal strength. Additional considerations include the degree of flap elevation, vascular zones of elevation, number and location of pedicles if used, and length of delay (11). Given the sheer variety of ways in which autologous breast reconstruction can be performed, the question of the most optimal technique using surgical delay is of great clinical value.

Despite comprehensive efforts to summarise the biological mechanisms by which surgical delay functions (2), there is no review yet exploring clinical outcomes of the various types of surgical delay in human subjects. As such, this paper aims to evaluate the current literature and determine the optimal surgical delay technique in abdominal-based flap surgery with regards to clinical outcomes. We present this article in accordance with the PRISMA-ScR reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-23-306/rc).

Highlight box

Key findings

- Surgical delay improves flap survivability.
- Transverse rectus abdominis muscle flaps had lower rates of flap loss and return to theatre, but higher rates of fat necrosis, wound infection, and abdominal bulge relative to deep inferior epigastric perforator flaps.
- The combination of surgical and vascular delay may be particularly beneficial to flap survivability.

What is known and what is new?

- Surgical delay has been previously described to induce neovascularization and numerous metabolic changes to enhance flap survivability.
- This scoping review describes the range of surgical delay techniques that have been used, and demonstrates that surgical delay results in reduced rates of complications in patients undergoing abdominal-based flap surgery.

What is the implication, and what should change now?

- Surgical delay should be considered in patients undergoing abdominal-based flap surgery.
- Further studies on surgical delay should be conducted to facilitate data collection and comparison between delay techniques, and outcomes in high-risk patients.

Methods

A scoping review of the literature was conducted across Embase, Medline, Cochrane, and PubMed, as presented in *Table 1* (last search conducted January 2022). Key search terms included "Surgical flaps", "Delay techniques", and "Abdomen", with synonyms and MeSH terms employed to capture as many relevant studies as possible. Slight differences in precise search terms used existed across the various databases due to the relative availability of certain MeSH terms. Of the 346 results, 9 studies were selected for final review, with data extraction being performed in parallel by two independent reviewers (*Figure 1*). Conflicts were resolved through consultation with the senior author.

Table 1 Exact search strategy used for PubMed (a similar search was conducted on the other databases with slight variances in the phrasing of MeSH terms)

Search term	Variation of search terms used	Field
Surgical flap	Flap surgery OR reconstruction	Title/abstract
AND Abdomen	Abdominal OR rectus	Title/abstract
AND Surgical delay	Delay techniques OR delay methods OR delay phenomenon OR therapy delay	Title/abstract

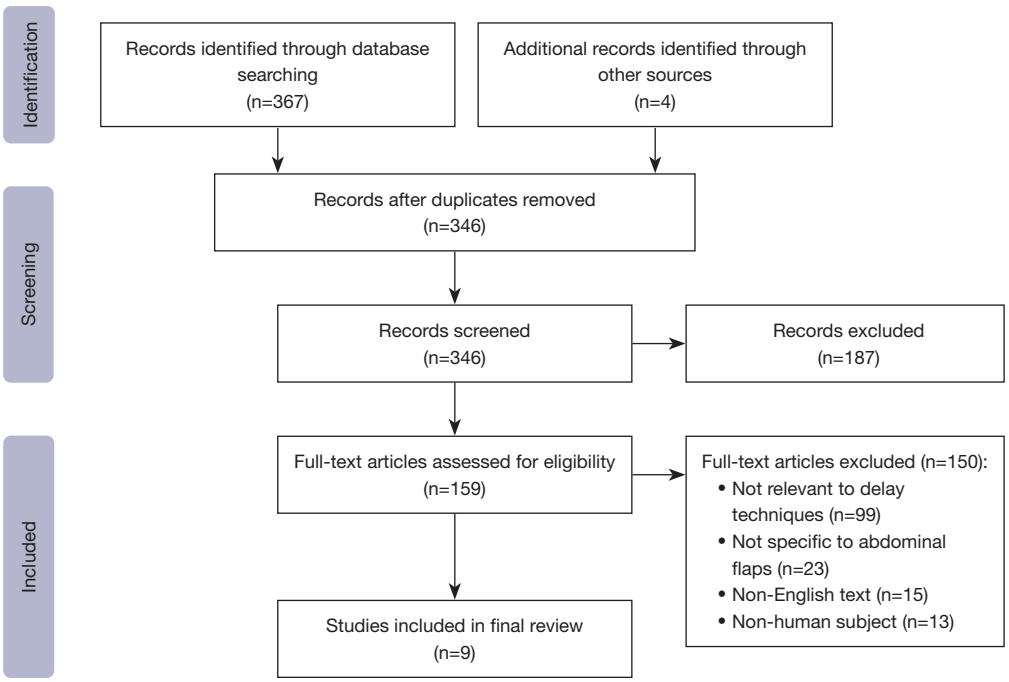

Figure 1 PRISMA diagram of screening process.

All included studies had to describe a method of surgical delay used in abdominal based flap surgery with respect to breast reconstruction. Details which were considered included length of delay, vessels ligated, whether reconstruction was unilateral or bilateral, and whether there was flap elevation, and to what degree. Further details noted were the flap zone, augmentation of surgical delay with other procedures such as supercharging, and duration of the surgery. Studies had to go on to discuss complications in the patient population. Complications which were considered included both the donor site and recipient site. Complications such as abdominal hernias, sepsis, fat necrosis, and flap necrosis, were considered.

Studies were excluded for a variety of reasons. Case reports were not included in this study. Non-English texts and studies using cadaveric or non-human subjects were excluded. Many studies discussed the delay phenomenon, however they utilised an angiographic method (with embolisation) instead of a surgical method, and thus were excluded from the study. Studies regarding surgical delay, but with sites utilised outside of the abdomen, such as the latissimus dorsi, or thigh, were excluded. Studies which were discussing flap-based breast reconstruction, but did not discuss the delay phenomenon, were excluded, as were studies whereby the sole outcome reported were patient-reported quality of life measures, rather than clinical outcomes.

Study design, delay technique and surgical outcomes were recorded and assessed qualitatively using the Methodological Index for Non-Randomised Studies (MINORS) score (12). Data pertaining to patient demographics, TRAM and DIEP flap techniques used, and

Table 2 Characteristics of included studies

Studies	Author(s)	Year	Country	MINORS score	Study design	No. participants
Delay in unipedicled TRAM flap reconstruction of the breast: a review of 76 consecutive cases (13)	Erdmann *et al.*	2002	USA	12	Case series	76
The surgically delayed unipedicled TRAM flap for breast reconstruction (14)	Hudson	1996	South Africa	12	Case series	7
A New Concept of Interval TRAM for Immediate Breast Reconstruction in Obese Women (15)	Khater *et al.*	2019	India	12	Case series	24
Surgical delay in TRAM flap breast reconstruction: a comparison of 7- and 14-day delay periods (16)	Restifo *et al.*	1997	USA	16	Prospective cohort	31
Influence of vascular delay on abdominal wall complications in unipedicled TRAM flap breast reconstruction (17)	Rickard and Hudson	2003	South Africa	14	Retrospective case review	15
Make Your Own Deep Inferior Epigastric Artery Perforator Flap: Perforator Delay Improves Deep Inferior Epigastric Artery Perforator Flap Reliability (18)	Shakir *et al.*	2019	USA	12	Case series	135
Clinical experience with the delay phenomenon in autologous breast reconstruction with the deep inferior epigastric artery perforator flap (19)	Guilherme and Rosson	2010	USA	11	Case series	6
Initial experience with laparoscopic inferior epigastric vessel ligation for delayed transverse rectus abdominus musculocutaneous flap breast reconstruction (20)	Trus *et al.*	2007	USA	12	Case series	130
The extraperitoneal laparoscopic TRAM flap delay procedure: an alternative approach (21)	Yenumula *et al.*	2011	USA	10	Case series	11

MINORS, Methodological Index for Non-Randomised Studies.

Table 3 Reported complication rates from surgical delay procedures in included TRAM and DIEP flap procedures

Complication/type of flap	TRAM (n=294)	DIEP (n=141)
Partial flap loss	8 (2.7%)	5 (3.5%)
Total flap loss	1 (0.3%)	3 (2.1%)
Fat necrosis	17 (5.8%)	11 (7.8%)
Wound infection	5 (1.7%)	0 (0%)
Hematoma	2 (0.68%)	3 (2.13%)
DVT	1 (0.3%)	0 (0%)
Seroma	4 (1.4%)	8 (5.7%)
Hernia	9 (3.1%)	0 (0%)
Abdominal bulge	7 (2.4%)	0 (0%)
Return to theatre	7 (2.4%)	26 (18.4%)

TRAM, transverse rectus abdominis muscle; DIEP, deep inferior epigastric perforator; DVT, deep vein thrombosis.

post-operative complications for each paper were extracted in parallel by two reviewers into duplicate Microsoft Excel spreadsheets. Conflicts were then identified and resolved. A summary of delay options and outcome measures was sought, and an optimal approach to delay presented.

Results

Nine studies were ultimately included for review. Included studies and study characteristics are presented in *Table 2*, with all studies reported after year 1996, and comprising levels of evidence case series or higher. There have not been any comparative studies or randomised studies.

The rates of post-operative complications following surgical delay in the pooled patient cohorts are presented in *Table 3*. Operations utilising TRAM flaps had fewer instances of flap loss and return to theatre than those using DIEP flaps, but higher rates of fat necrosis, wound infection, and

abdominal bulge.

Patient risk factors

The inclusion of specific patient demographics shows marked variability between the published studies. The known impact of smoking and obesity on flap outcomes and donor site complications have predicated patients considered to have an elevated risk for autologous breast reconstruction. Erdmann *et al.*, noted that smoking was associated with a statistically increased incidence of partial flap necrosis and two of the five patients with flap necrosis were also classified as obese (13).

Another study, Khater *et al.* exclusively investigated the role of delaying pedicled TRAM flaps in obese women. Khater acknowledges that vascular delay in this population is not a new concept however has introduced a modified skin incision and flap elevation technique. Despite these modifications, fat necrosis was reported in 33.3% of cases however the authors hypothesize that this can be attributed to the small cohort size (n=25).

Rickard and Hudson's study was the only study to directly compare complications between delayed and non-delayed populations. Forty percent of the delay cohort were either current or past smokers compared to 25% of the non-delayed group. Despite the known association between smoking and a high incidence of abdominal flap necrosis, there were none such complications within the delay group. The authors theorise that this is a direct influence of delay as without confounding factors of age and obesity, there was still an expected higher incidence of fat necrosis.

Though Rickard and Hudson show promising outcomes, the overall minimal comparative data within the literature makes analysis of the impact of the delay phenomenon on patients with risk factors difficult to achieve.

Surgical technique of delay

Breast autologous reconstruction utilising anterior abdominal wall tissue can derive their vascular supply from the perforators of either the deep superior epigastric artery (DSEA) or the deep inferior epigastric artery (DIEA). The latter is the dominant supply to the anterior wall and its musculocutaneous perforators form the basis of many available tissue flaps in this region. This territory of supply has been widely investigated and is described to compose of four perfusion zones; zone 1 being of greatest vascularity and successive zones of decreasing vascularity. Reduced calibre or 'choke' arterial connections define and link these adjoining vascular territories. The delay phenomenon acts to enhance perfusion of adjacent zones by dilating these choke vessels following division of vascular supply to one territory.

The combination of the known axial supply to the anterior abdominal wall and the delay phenomenon results in a degree of consistency regarding surgical delay technique. Seven studies describe a pedicled TRAM breast reconstruction. This flap is reliant upon the DSEA and accordingly these studies all describe ligation of the inferior abdominal wall vasculature. Both superficial and deep inferior epigastric vessels are specifically noted in all studies excepting Erdmann *et al.* and Trus *et al.* (13,20). The majority of studies also describe bilateral vessel ligation despite only Rickard and Hudson describing bilateral breast reconstruction (17).

The differentiation in surgical technique lies in the inclusion of an extended skin incision and elevation of flap tissue. The sentinel paper describing vascular delay of the TRAM flap utilises 4–6 cm incisions overlying the inferior epigastric vessels in line with the inferior extent of the flap. However, Erdmann *et al.* forms a clear distinction between pure vascular delay and surgical (skin incision) delay and subsequently adopts a three-fourths inferior flap incision (13). As previously mentioned, Khater *et al.* has introduced a new technique to the literature. The study describes a routine vascular delay of the inferior epigastric vessels and simultaneous total skin delay including flap elevation of zones 3 and 4 which is then re-sutured *in situ* to the abdominal wall (15). This modification follows existing literature that a combination of delay techniques is superior to vascular delay alone especially in high-risk patient groups.

Guilherme and Rosson and Shakir *et al.* both describe the delay of DIEP free flaps. Diverging from the traditional axial vessel ligation to achieve vascular delay, both studies instead perform vascular delay at a perforator level. Guilherme and Rosson use pre-operative CT angiogram to pre-plan appropriate perforators, superior and inferior borders of the abdominal flap are incised, and minor perforator vessels are ligated. The flap is then connected to the body only via lateral skin bridges and the selected perforator. Shakir similarly adopts pre-operative imaging to select perforators for preservation. Perforator dissection is achieved via an infra-umbilical T incision and both minor perforators and the superficial system are ligated.

As evidenced by the variety of surgical approaches in

Table 4 Reported techniques for surgical delay, associated study characteristics, and their reported outcomes

Study title/parameters	SIEA ligated	DIEA ligated	Length of delay (days), mean/ median (range)	Type of flap	Study design	Age (years), mean/mean ± SD, median	Flap loss (%)	Fat necrosis (%)
Delay in unipedicled TRAM flap reconstruction of the breast: a review of 76 consecutive cases	No	Yes	13.9	TRAM	Case series	47.4	0	6.6
The surgically delayed unipedicled TRAM flap for breast reconstruction	Yes	Yes	7	TRAM	Case series	46.6	0	42.9
A New Concept of Interval TRAM for Immediate Breast Reconstruction in Obese Women	Yes	Yes	7	TRAM	Case series	47.6±3.45	20.8‡	33.3
Surgical delay in TRAM flap breast reconstruction: a comparison of 7- and 14-day delay periods	Yes	Yes	7 & 14†	TRAM	Prospective cohort	NR	9.7‡	3.2
Influence of Vascular Delay on Abdominal Wall Complications in Unipedicled TRAM Flap Breast Reconstruction	No	Yes	14 (6.8–116)	TRAM	Retrospective case review	41	0	0
Make Your Own Deep Inferior Epigastric Artery Perforator Flap: Perforator Delay Improves Deep Inferior Epigastric Artery Perforator Flap Reliability	No	Yes	14	DIEP	Case series	52.1	5.2‡	8.1
Clinical experience with the delay phenomenon in autologous breast reconstruction with the deep inferior epigastric artery perforator flap	No	Yes	15.8	DIEP	Case series	51.7	1.7	0
Initial experience with laparoscopic inferior epigastric vessel ligation for delayed transverse rectus abdominus musculocutaneous flap breast reconstruction	NR	Yes	7 & 14†	TRAM	Case series	49	0.8	0
The extraperitoneal laparoscopic TRAM flap delay procedure: an alternative approach	Yes	Yes	14	TRAM	Case series	55	0	0

†, these studies contained comparison groups with varying length of surgical delay; ‡, these studies reported the rate of both complete and partial flap loss. SIEA, superficial inferior epigastric artery; DIEA, deep inferior epigastric artery; SD, standard deviation; TRAM, transverse rectus abdominis muscle; NR, not reported; DIEP, deep inferior epigastric perforator.

delaying an abdominal based flap, no one surgical technique has proven superior (see *Table 4*). In fact, the range of surgical options available allow surgeons to individualise their approach to the patient and flap reconstruction. Though the literature suggests that a combination of vascular and surgical delay can optimise tissue perfusion, the degree of tissue elevation and its utility in free flap surgery has not yet been established.

Discussion

In 158 pedicled TRAM flap procedures without delay, flap complications occurred in 34% of patients. In the included studies, out of a population of 435 patients, complications occurred in 26.9% of patients. This was despite the fact that in many of these patients, significant comorbidities existed, the reason for delay being employed in the first case. This

would indicate that surgical delay does reduce complications in patients for this procedure.

Restifo *et al.* (16), in a study on TRAM flap reconstructions, noted there was significant dilation and increase in blood flow in both the superficial inferior epigastric artery (SIEA) and DIEA when surgical delay was carried out. Other research has shown similar observations (1-3,17,22), as well as finding that there is a proliferation in, dilation, and reorientation of choke vessels, which supply regions most likely to undergo necrosis in a flap procedure. Morris and Taylor detailed the increase in diameter of choke vessels and reduction in vessel wall thickness when compared to contralateral control vessels that did not undergo delay, especially so between the 48- and 72-hour period (23). It is thought that the reorientation of vessels occur results from the shift of nutritive flow from capillaries following sympathetic or ischemic stress (24). There is some debate as to the relationship between the timing of delay and the onset of choke vessel enlargement; however, Milton and Ghali *et al.* suggest 2 weeks as the optimal time for vascular delay before tissue transfer (25). These data suggest that surgical delay may induce physical changes that increase viability of a flap prior to elevation.

A discussion of the biochemical changes induced by surgical delay is warranted as it may help explain the reduction in complications. Research into the mechanism of action of the delay phenomenon has also shown that immediately after the procedure, there is a period of vasoconstriction in the flap due to high levels of noradrenaline. This is due to division of the sympathetic nerves in the region prompting a hyperadrenergic state thought to last up to 30 hours—the resulting vasoconstriction of precapillary sphincters in particular have been implicated in the relative ischemia that follows (26). When these nerves run out of noradrenaline, there is then vasodilation, which improves nutrient flow, making the flap more likely to survive. Preliminary research has also demonstrated that by inducing relative ischemia, there is metabolic compensation in the flap, with post procedural changes including reduced dependence on nutrients, and reduced rates of cell death, among other positive changes (2,22). A later effect of surgical delay is the release of endothelial progenitor cells from bone marrow, these cells have been seen to move to areas of ischemia within the flap, and form new blood vessels (2). This occurs later than the earlier mentioned processes, and has been seen to take effect by day 14 of delay.

Preoperative CTA represents the modality of choice in preoperative imaging for flap planning. It may provide guidance as to the operative plan, the safety of flap harvest, and improve the survivability of the flap (3). Alonso-Burgos *et al.* found CTA to identify main arterial perforators successfully in all six of their patients and demonstrate concordance with intra-operative findings, while alerting surgeons to individual anatomical variability (27). While the use of preoperative doppler and duplex ultrasound have been supported (28), it may also result in a high proportion of false positives due to the detection of very small, narrow-diameter perforators unsuitable for selection (29).

DIEP flaps are known for having a higher rate of fat necrosis (17.4%) than free TRAM flaps (6.9%) (18,30). Lee *et al.* noted that DIEP flaps are a newer form of flap surgery, and minimise donor site injury, sacrificing blood supply in return. This explains their relatively higher rate of fat necrosis. Shakir *et al.* attempted to augment the DIEP procedure with surgical delay, so as to gain the aesthetic benefit of a DIEP flap surgery, while minimising complications. In 135 operations involving 215 flaps, the rate of flap necrosis was 5.1%, with similarly low rates of other complications. The novel 2-stage method used to induce vascular delay in these patients would suggest that delay prior to either DIEP or TRAM flap elevation does have beneficial results. Comparison in outcomes between techniques themselves remain challenging due to differences in outcomes reported between studies. While all studies reported rates of flap loss and fat necrosis, many did not detail the incidence of flap skin necrosis, returns to theatre, or donor site complications such as haematomas and seromas. Amongst the papers reporting flap loss, only Khater *et al.*, Restifo *et al.*, and Shakir *et al.* described if the loss was partial or complete (15,16,18).

The heterogeneity of study samples and methodology present in the few studies exploring delay introduces difficulty in obtaining comparative data. It is challenging at this stage, therefore, to provide definitive guidelines as to indications for delay and the optimal technique. The findings of this review, however, suggest that delay—in particular the combination of surgical and vascular delay—confers benefit to flap survivability and reduces the rate of complications, particularly in high-risk demographics such as smokers and obese patients.

Existing literature seems to correlate with what we have observed through a review of the studies. Wang *et al.* (31) found that vascular delay improved flap survival up to 3 times as much when compared to a control, while other studies also demonstrated improved flap viability (32). It

must be noted that the majority of studies in this scoping review were case series, and thus there is much space for further research on surgical delay and the effects it has on autologous flap-based breast reconstruction.

Conclusions

The current data supports delay as a viable method for reducing rates of complications in such procedures. Further data is needed in order to compare the existing techniques.

Acknowledgments

Funding: None.

Footnote

Reporting Checklist: The authors have completed the PRISMA-ScR reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-23-306/rc

Peer Review File: Available at https://atm.amegroups.com/article/view/10.21037/atm-23-306/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-23-306/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Cite this article as: Rozen WM, Yogaraj V, Siddiqui M, Lok E, Hunter-Smith DJ. Surgical delay in abdominal based flap surgery: a scoping review. Ann Transl Med 2023. doi: 10.21037/atm-23-306