Thoraco-Aorto-Bi-Femoral Bypass for extensive aorto-iliac disease in patients with anatomic constraints for standard infrarenal aortic bypass

Christos V. Ioannou, Stella Lioudaki, Emmanouil Tavlas, Nikolaos Daskalakis, Alexandros Kafetzakis, Christos Chronis, Kyriaki Papageorgiou, IfigeniaTzartzalou, George Tzouliadakis, Alexandra Papaioannou*, Nikolaos Kontopodis

Vascular Surgery Unit, Department of Cardiothoracic and Vascular Surgery & *Department of Anesthesiology, University of Crete Medical School, Heraklion, Crete, Greece

Abstract:

Introduction: Endovascular techniques are increasingly used to treat aorto-iliac occlusive disease that causes disabling claudication or chronic limb threatening ischemia (CLTI). Nevertheless, open surgical reconstruction is still needed in patients with extensive and diffuse disease and aorto-bi-femoral or aorto-bi-iliac bypass is the standard of care for patients fit to undergo a major surgical intervention. Specific anatomic constraints such as juxtarenal arterial disease and/or hostile abdomen may increase the technical difficulty of the procedure and the risk for possible complications. In these cases, other surgical techniques such as axillo-bifemoral bypass have been employed. Thoraco-aorto-bi-femoral bypass (TABFB) has also been used in this setting, but data are limited. We aim to report a single-center's experience with this technique.

Materials & Methods: This is a single institution, retrospective descriptive study including all patients undergoing TABFB during an 8-year period, from 05/2013 till 05/2021. Baseline characteristics, peri-operative and follow-up data were collected.

Results: In total TABFB was attempted in 10 patients, 6 with CLTI and rest pain, 3 with wet gangrene and in 1 with disabling claudication and an infected, patent, axillo-bifemoral bypass. All patients presented juxtarenal aortic disease, while 2 had a previous aortic procedure (one occluded aorto-bi-femoral bypass and one case of occluded kissing stents). In one patient, the procedure was converted to axillo-bi-femoral bypass, because he could not tolerate left lung isolation. All patients were admitted to the intensive care unit immediately postoperatively, where they stayed for a mean of 2.1±1.1 days. No peri-procedural mortality was recorded, while mean hospitalization time was 13.9±3.9 days. All patients presented a significant improvement of the ankle-brachial index, with a mean postoperative value of 0.86±0.16, compared to 0.27±0.15 preoperatively. During a mean 32-month follow-up, limb salvage was achieved in all cases, while 2 patients died due to unrelated causes. Primary patency was 100%.

Conclusion: TABFB presents favorable peri-operative and mid-term results in this small case-series of selected patients with aorto-iliac occlusive disease and anatomic constraints for standard aorto-bi-femoral bypassthat was performed in a specialized tertiary center. Further follow-up and more cases are needed to establish efficacy and applicability of this technique.

Keywords: Aorto-femoral bypass, juxtarenal aortoiliac occlusive disease, hostile abdomen, renal artery embolism, extra-anatomic bypass, thoracotomy

INTRODUCTION

Aorto-iliac occlusive disease (AIOD) may significantly affect quality of life of patients causing intermittent claudication (IC) or even pose a threat for the limb if it causes chronic limb threatening ischemia (CLTI). Currently, endovascular interventions are becoming increasingly popular for the treatment of these lesions, having replaced open surgery in most cases.[1] Moreover, accumulated experience along with significant technologic advances of endovascular means, are constantly expanding indications of endovascular treatment.[2] Indeed, complex disease patterns such as total infra-renal occlusion which were considered as an absolute indication for open repair, are currently treated using endovascular techniques with favorable outcomes.[3] Nevertheless, aorto-bi-femoral and/or aorto-bi-iliac bypass is still considered the gold standard in patients with extensive AIOD who are good surgical candidates. Since disease patterns that can be treated endovascularily are increasingly expanding, anatomic complexity of patients

Author for correspondence:

Nikolaos Kontopodis, MD, MSc, PhD

Assistant Professor of Vascular Surgery, University of Crete, Medical School, Heraklion, Crete, Greece
Tel: +30 6948202539, +30 2810 392379
E-mail: kontopodisn@yahoo.gr, nkontopodis@uoc.gr
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undergoing open surgical reconstruction has progressively increased.[4] Therefore, currently patients with aorto-iliac disease not amenable to endovascular treatment often present juxtarenal disease, which make standard aorto-bi-femoral bypass technically challenging and increase the potential for complications. Alternative surgical techniques may be used in this setting, such as axillo-bi-femoral bypass, but these present an inferior hemodynamic result and more importantly, inferior long-term outcomes.

The thoracic aorta has been used as inflow site for peripheral arterial bypass but data regarding this operation are very limited due to limited experience in most institutions. With the current report we aim to present our experience with the use of this technique in selected cases requiring bypass for aorto-iliac disease in the presence of anatomic constraints for standard infrarenal aorto-bi-femoral bypass.

MATERIALS AND METHODS

Study design

This is a single center retrospective, descriptive study including all consecutive patients who had a thoracic aorto-bi-femoral bypass (TABFB) from 05/2013 to 05/2021. In our institution, patients with IC undergo interventional or surgical treatment on a selective basis. Young and fit patients with disabling claudication due to extensive AIOD (TASC C and D lesions) are typically treated with standard infrarenal aorto-bi-femoral bypass. Older and more compromised patients with a similar anatomical distribution are mostly managed conservatively. In case of patients who are considered poor surgical candidates for open repair, an endovascular approach is attempted if the endovascular recanalization is considered feasible. An axillo-femoral bypass is an alternative treatment strategy in this latter group of patients if the endovascular approach fails or if this is considered not feasible. TABFB is currently used only in low or medium risk patients as indicated by an American Society of Anesthesiology (ASA) score 2, who suffer from CLTI due to extensive AIOD in the presence of specific indications. These are:

- significant juxtarenal involvement which makes manipulation of the aorta problematic,
- hostile abdomen making access to the aorta difficult and
- previous failed aortic intervention.

Due to the fact that during the procedure the left lung is isolated, special attention was given to the pulmonary status of the patients and pulmonary status stage 1 (asymptomatic or mild dyspnea on exertion, mild chronic parenchymal radiograph changes, pulmonary function tests 65% to 80% of predicted) as reported in the SVS clinical commorbidity score system[5] was the minimum requirement for patients to be considered suitable candidates for TABFB. Patients with more advanced pulmonary disease were excluded.

Technique

Under combined thoracic epidural and general anesthesia and with the use of double lumen endotracheal tube, the patient is placed with the pelvis supine and the thorax rotated to the right by 60°, with the left arm hanging to the right. The surgical table is then bent in the middle to place the patient in a semi-right, lateral, jack-knife position to facilitate maximal separation of the iliac crest and costal margin. A posterolateral thoracotomy is performed on the 8th or 9th intercostal space depending on each patient's body habitus. Ventilation of the left lung is ceased and following its collapse, the inferior pulmonary ligament is divided, and the parietal pleura is opened to expose the distal descending thoracic aorta. A vessel loop is placed to offer vessel control. Care should be given to avoid injuring any intercostal arteries. Simultaneously, exposure of the distal outflow vessels is achieved depending on the patient's anatomy or pathology, usually through bilateral longitudinal inguinal incisions and exposure of the femoral arteries. In cases where a femoral area is infected and needs to be avoided, the graft can be passed through the obturator foramen to the superficial, profunda femoris or popliteal artery. If the obturator foramen on the right is to be used then a right oblique retroperitoneal incision is needed, in order to expose the obturator foramen and to facilitate secure passage of the graft limb.

The left femoral incision is expanded cranially about 10-15 cm supra-inguinally in order to facilitate entrance to the left retroperitoneal space, after mobilization of the inguinal ligament. An alternative technique to gain access to the retroperitoneal space would be through an oblique lower abdominal incision, the choice between the two techniques being based on each individual surgeon's experience and preference. The peritoneum is bluntly dissected posterior to the left kidney up to the left hemi-diaphram. A small incision is performed on the diaphragm, under direct visualization via the thoracotomy, at the boundary between its tendonous and muscular portion of the diaphragm, and the graft is passed bluntly down to left retroperitoneal incision (Figure 1).

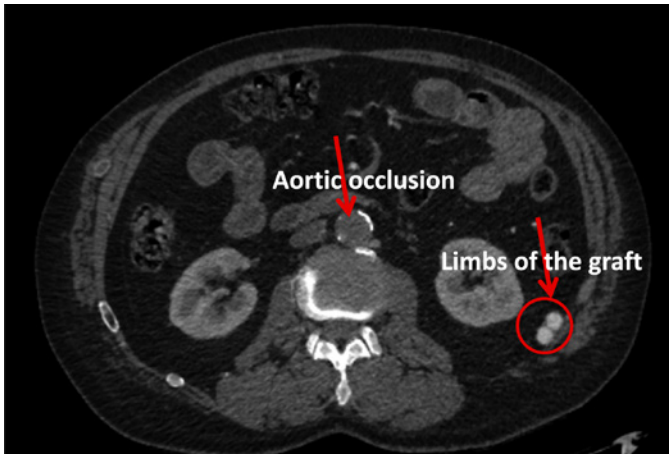

Figure 1: Retroperitoneal course of the graft as displayed in a postoperative axial CT image.

After patient's heparinization (80 IU / kg) and partial clamping of the descending aorta with a Satinsky clamp, a bifurcated synthetic graft 14/7 or 16/8 mm (according to distal

target vessel size) is anastomosed to the aorta (Figure 2).[6] The left limb of the graft is anastomosed to the common femoral or the profunda femoral artery having passed through the femoral foramen, but other distal sites can also be used (superficial femoral or popliteal artery). Usual graft limbs are too short to directly reach the right target vessel thus another tube graft (6-8 mm diameter) is anastomosed at the retroperitoneal access site and the right limb is passed in a preperitoneal space, behind the rectus abdominis muscle, over the bladder and through the right femoral foramen to be sutured to the contralateral common femoral artery (Figure 3). A retroperitoneal route for the right limb has also been described, but most studies use a preperitoneal route, similar to the present report.[7-9] A chest tube is placed and the surgical incisions are closed. The epidural anesthesia catheter is not immediately removed to provide post-operative analgesia, and is usually removed after the 3rd - 4th post-operative day, after which intravenous or oral analgesics are continued. If there is no specific reason to do otherwise (i.e., patients with Atrial Fibrillation), patients are prescribed single anti-platelet therapy, preferentially with clopidogrel.

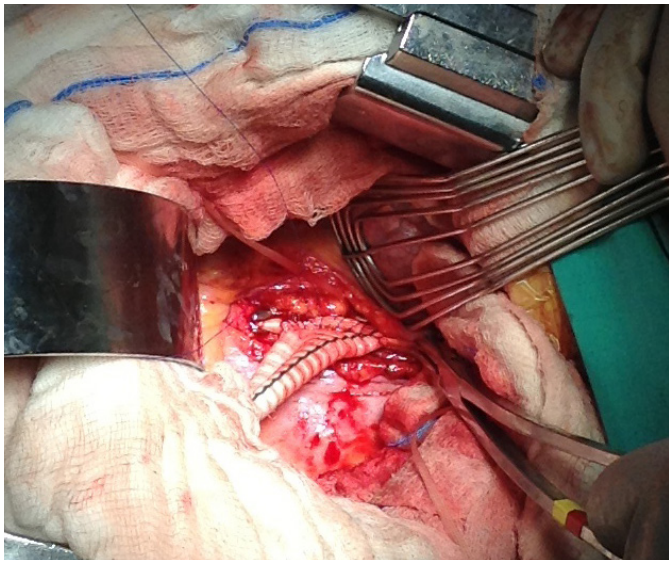

Figure 2: Intra-operative photograph showing the thoracic incision, the side clamp of the thoracic aorta and the construction of the proximal anastomosis.

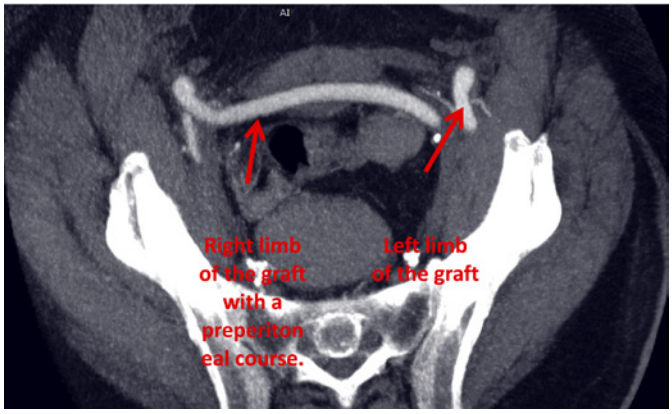

Figure 3: The preperitoneal course of the right limb is shown

Outcomes

Baseline information such as demographic data and comorbidities were recorded. Bilateral preoperative Ankle Brachial Index (ABI) values were also recorded. Intra- and peri-operative variables such as procedural duration, blood loss, Intensive Care Unit (ICU) stay, length of hospitalization, per-operative morbidity and mortality were analyzed. Severity of complication was graded according to the Society of Vascular Surgery reporting standards.[10]

During follow-up, patients were evaluated 3 months after the index procedure and annually thereafter. During follow-up visits the patients were queried for new symptoms, a physical examination was performed, and ABI was recorded.

Statistical report

Quantitative data are presented as mean ± standard deviation, and categorical data as numbers and rates (%).

RESULTS

Patient characteristics

From May 2013 to May 2021 TABFB was attempted in 10 patients for juxtarenal aortoiliac occlusive disease in our department. All patients were male with a mean age of 62.5±9.6 years and presented the typical comorbidities of a cohort with CLTI such as high rates of smoking, hypertension, and hyperlipidemia. Mean pre-operative ABI was 0.27±0.15. Six patients presented with CLTI and rest pain (Rutherford's category 4), 3 patients had ischemic necrosis and wet gangrene (one case with Rutherford's category 5 and two cases Rutherford's category 6 lesions) in the toes and 1 patient had disabling claudication (Rutherford's category 3) in the presence of an infected (patent) axillo-bi-femoral graft. All patients presented juxta-renal arterial disease with significant atherosclerotic burden and calcification at the level of the renal arteries, which was judged unsuitable for clamping and/or construction of a proximal infrarenal / juxtarenal anastomosis (Figures 4 and 5) or had an abdomen considered to be hostile. Except for the patient with the patent axillo-bi-femoral bypass, 2 more patients had a previous revascularization procedure, one had an occluded aorto-bi-femoral bypass performed 4 years ago and the other had undergone kissing stenting of the aortic bifurcation and common iliac arteries which were occluded. Among 20 limbs, the Superficial Femoral Artery (SFA) was the outflow vessel in 10 cases, while in the remaining 10 the target was the PFA, in the presence of an occluded SFA. No outflow procedures such as femoro-popliteal bypass were performed in any of the patients. Femoral endarterectomy was required in the recipient femoral artery in 5 cases. In the patient with the previous infected Axillo-bi-femoral graft, this was partially removed at the right groin while the rest of the graft did not show clinical or radiological signs of infection and it was not removed. The right limb of the TABFB was directed to the superficial femoral artery from an extra-anatomical plane, through the obturator foramen. Patients' characteristics are reported in Table 1.

Figure 4: Juxtarenal aortic disease in a patient that underwent TABFB.

Figure 5A **Figure 5B**

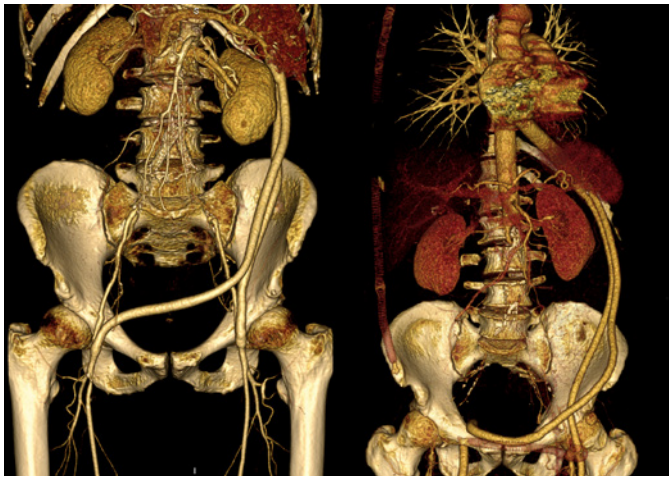

Figure 5: 3-Dimensional reconstruction of two cases with TABFB. Note that in Panel A there are occluded kissing stents in the infra-renal aorta while in Panel B, the right limb is directed through the obturator foramen to avoid an infected groin (facilitated via another oblique incision at the right lower abdominal quadrant).

Age (years)	62.5±9.6
Gender	10 Male: 0 Female
Smoking	10/10 (100%)
Arterial hypertension	8/10 (80%)
Hyperlipidemia	7/10 (70%)
Diabetes	3/10 (30%)
Renal insufficiency	0/10 (0%)
CAD	3/10 (30%)
COPD	2/10 (20%)
Previous Revascularization	3/10 (30%)
Rutherford's Category	Category 3 n=1, Category 4 n=6, Category 5 n=1, Category 6 n=2

Table 1: Baseline characteristics of the patient cohort. CAD coronary artery disease, COPD Chronic Obstructive Pulmonary Disease

Peri-operative variables

The operation was successfully completed in all but one patient. This patient presented moderate Chronic Obstructive Pulmonary Disease (COPD) and could not withstand intra-operative left lung isolation, so in this case the thoracic wound was closed and the procedure was converted to an axillo-bi-femoral bypass. Among 9 patients in whom the TABFB was completed, mean procedural time was 190±43 min. Mean blood loss was 650±175 ml. All patients were admitted to the ICU immediately postoperatively, where they stayed for a mean of 2.1±1.1 days. At the end of the procedure 4 patients were extubated on the operation table, while in the remaining 5 patients the double lumen was replaced by a single lumen endotracheal tube and extubation was achieved later during the day. Six patients were hemodynamically stable immediately post-operatively, while 3 patients needed minor vaso-constrictive support for a few hours. No peri-procedural mortality was recorded. One patient presented bleeding in the thoracic cavity in the 2nd post-operative day and he underwent surgical exploration where a hemostatic suture was placed in the proximal anastomosis. Other adverse events recorded were, one patient who suffered a myocardial infarction during the 4th postoperative day and another one who presented a refractory pleural fluid collection which required a chest tube for several days and prolonged length of hospital stay. All patients were discharged in good condition, after a mean of 13.9±3.9 days. Postoperative ABI presented a mean value of 0.86±0.16. Among 18 limbs treated with TABFB 15 were markedly and 3 moderately improved according to Rutherford's scale for gauging changes in clinical status.[10] These results are summarized in Table 2.

Procedural duration (min)	190±43
Blood loss (ml)	650±175
ICU stay (days)	2.1±1.1
Length of stay (days)	13.9±3.9
Major complications	2/9 (22%)
Reinterventions	1/9 (11%)
Limb Salvage	18/18 (100%)
ABI	PreOp 0.27±0.15, PostOp 0.86±0.16
Peri-procedural mortality	0/9 (0%)

Table 2: Procedural details and peri-procedural outcomes. ABI: Ankle-Brachial Index, ICU: Intensive Care Unit

Follow-up data

After a mean of 32 months follow-up ,7 of 9 patients were alive. Two patients died 15 and 24 months after the procedure due to unrelated causes (one case of lung cancer and one case of myocardial infarction). Limb salvage was achieved in all cases. Primary patency was 100%, while there were no cases that required a secondary procedure to preserve or restore patency of the bypass. Symptoms of peripheral arterial disease were not reported by any of the patients during follow-up. The mean value of the last ABI available was 0.9±0.13

Discussion

The current report describes a contemporary single center

experience with the use of TABFB in a selected group of patients, in whom endovascular recanalization was not feasible and direct surgical reconstruction with standard infrarenal aorto-bi-femoral bypass was considered risky due to specific anatomic constraints. Juxtarenal atherosclerotic disease may be present in 10%-12% of all aorto-iliac occlusions and in this case clamping of the aorta in a supra-renal (or even supra-mesenteric or supra-celiac) level may be required.[7,11] In this case the potential for complications is high and it has been previously reported that all relevant outcomes are significantly worse when the proximal clamp is placed suprarenally. Specifically, overall complication rate has been indicated to increase from 37% to 61%, 30-day mortality from 2.9% to 6.1%, and postoperative renal insufficiency from 7.7% to 29.3%.[12] Similarly, mesenteric occlusive disease has been demonstrated in 20% of patients with lower limbs peripheral arterial disease and although this may not be clinically apparent in most patients and does not require any interventional treatment, it certainly poses significant technical challenges during direct aortic revascularization.[13,14]

In circumstances as those mentioned above, TABFB may be considered as an alternative to infrarenal aorto-bi-femoral bypass. This later procedure is still considered the standard of care for patients with aorto-iliac occlusion because it has been shown to be accompanied by an operative mortality 2-5%, a systemic morbidity rate of 15-20% and an excellent primary patency rate >85% after 5-years of follow-up.[15-17] Although this is considered a major vascular procedure and compares unfavorably with endovascular techniques in terms of periprocedural mortality, morbidity and length of hospital stay, it provides a durable outcome with superior technical success and primary patency rates, although primary assisted patency may be comparable with that of novel endovascular procedures like Covered Endovascular Reconstruction of the Aortic Bifurcation (CERAB).[17-19] Nevertheless, in cases with juxtarenal occlusive disease neither of these techniques may be suitable and in such occasions TABFB may provide a safe and durable therapeutic alternative.

According to our results, despite being a major procedure, TABFB can be offered at a low rate of peri-procedural mortality and major morbidity. At the same time, an excellent hemodynamic result is achieved, since the descending thoracic aorta is often free of disease and serves as an exceptional inflow site. The fact that aortic clamping is only partial, is a major advantage of this procedure, since intra-abdominal organs are not subjected to any ischemia time, resulting in low complication and mortality rates. Previous research has indicated that supra-renal cross clamp time is the most critical determinant of the possibility of serious complications or death.[20] In the case of TABFB the effect of aortic cross clamp is significantly blunted by the fact that antegrade aortic flow continues uninterrupted throughout the operation, even when constructing the proximal anastomosis. Considering that the descending thoracic aorta is somewhat larger than the abdominal aorta, even with an approximately 50% reduction of the aortic lumen during partial clamping, as estimated by our experience, the remaining lumen is more than adequate to fully supply the lower body during the anastomosis. Previous studies report mostly similar results with the use of TABFB. A recent study reviewed patients that received this procedure in a single institution between 2002 and 2017 and included 41 cases recording a 30-day mortality rate of 5%, a 3-year graft patency of 80%, a freedom from major adverse limb events of 70% and a 5-year survival of 93%.[8] An additional contemporary study evaluated 20 patients, reporting no perioperative death and excellent patency rates of 100% at 1-year and 94% at 5-year follow-up.[7] Passman et al reported the largest cohort of patients undergoing TABFB (50 cases) up to date, reporting similarly favorable outcomes.[9]

Our study along with previous reports delineates the indications of TABFB. Except for juxtarenal aortic disease, the presence of primary aortic procedures such as a previous aorto-bi-femoral bypass, graft infection, hostile abdomen and horseshoe kidney, all may be accounted as relative indications for TABFB. According to our experience, we speculate that this procedure could pose a less severe physiologic insult to patients compared to standard aorto-bifemoral bypass because in the small patient cohort reported here, partial aortic clamping was well tolerated from patients, so as the need for hemodynamic support by the anesthetic and intensive care teams was reduced and patient recovery was shortened. Additionally, it possibly presents a superior hemodynamic effect compared to axillo-bi-femoral bypass which results in favorable long-term patency and limb salvage rates. Remarkably, in our series 100% primary patency and limb salvage was observed, even in patients with outflow disease (occluded SFA). Of course, similarly to any surgical/interventional procedure, adequate experience with the use of this technique is important if proper patient selection and optimum outcomes are to be achieved. Moreover, patients with significant coexistent systematic disease may not be suitable candidates to undergo TABFB. In our experience, pulmonary status of the patients represents the most significant predictor of intraoperative and postoperative complications. Patients with significant deterioration of respiratory function may not tolerate left lung isolation, which resulted in one case of conversion to axillo-bi-femoral in the current series and also may predispose to a higher susceptibility of infection, atelectasis and pleural effusion postoperatively. In these cases, axillo-bi-femoral bypass may be a more reasonable therapeutic choice.

CONCLUSION

TABFB was performed with low mortality and morbidity rates and provided excellent short and mid-term results in selected patients with extensive AIOD and juxtarenal aortic involvement or hostile abdomen, treated in a specialized tertiary center. Further follow-up and more cases are needed to establish efficacy and applicability of this technique.

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