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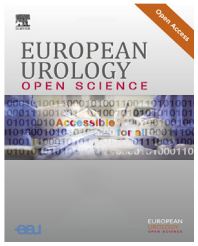

Surgery in Motion: Open Science

Robot-assisted Management of Complex Ureteral Stenosis in Kidney Transplant Patients: Multicenter Case Series and Description of Surgical Techniques

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Abstract

Background and objective: Ureteral stenosis following renal transplantation can occur in up to 10% of patients. Initial management, after kidney drainage, may include endoscopic balloon dilation ± laser incision. In case of recurrence after a primary endourological approach, strictures >1–3 cm, or complex anatomy in transplant patients, ureteral reconstruction should be performed. A robotic approach may reduce morbidity in this fragile population. We describe our case series of robot-assisted surgical treatments for ureteral stenosis in kidney transplant patients.

Methods and surgical procedure: We included 29 renal transplant patients who suffered from ureteral stenosis in whom ureteral reconstruction was performed at three referral centers from November 2019 to March 2024. Different approaches were used: ureteroneocystostomy (with or without an antireflux tunnel or a Boari flap), ureteroureterostomy, and pyeloureterostomy using the native ureter (ipsilateral or contralateral).

Key findings and limitations: All cases were performed using the Da Vinci Xi robotic system and completed successfully without intraoperative complications. The median pre- and postoperative (3 mo) glomerular filtration rates were 45 (interquartile range [IQR] 31–60) and 46 (IQR 31–58) ml/min, respectively. The median hospital stay was 4 (IQR 3–6) d. Postoperative complications were limited (21% Clavien-Dindo ≤2 and 10% Clavien-Dindo ≥3). Of 29 patients, 28 (97%) were

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free from nephrostomy or JJ stent at a median follow-up of 18 (IQR 13–34) mo. Our retrospective findings advocate confirmation through prospective data.
Conclusions: We demonstrate the safety and feasibility of robot-assisted ureteral reconstruction in kidney transplant patients with ureteral stenosis, allowing high-quality realignment of the urinary tract, quick recovery with a low complication rate, and good preservation of renal function in this fragile population.
Patient summary: We demonstrate several robot-assisted ureteral reconstruction options for kidney transplant patients suffering from ureteral stenosis. We found these techniques to be safe and effective, with low complication rates and good preservation of the renal function.
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1. Introduction

Ureteral complications following renal transplantation are common and include mainly ureteral stenosis (0.6–10.5%), vesicoureteral reflux (1–86%), urinary leakage (0–9.3%), and acute graft pyelonephritis (13%) [1]. As these complications may potentially lead to graft dysfunction or loss, and expose the recipient to an increased risk of morbidity and mortality, their management is of utmost importance. When treated by an experienced team, ureteral complications can be managed with high success rates, salvaging the transplant with graft survival rates equivalent to those in a matched control group of transplant recipients and excellent functional outcomes [2].

Ureteral stricture in transplant recipients is considered clinically significant when persistent hydronephrosis occurs in association with impaired renal function. Usually, this is initially managed with a nephrostomy tube and an antegrade pyelogram to evaluate stricture length and position. The European Association of Urology (EAU) guidelines recommend endoscopic incision and percutaneous balloon dilation for short (<3 cm) strictures, with highest success rates in strictures <1 cm [1]. In case of stricture recurrence, long strictures, or complex anatomy in transplant patients, ureteral reconstruction should be performed. Robotic surgery may further reduce morbidity and recovery times compared with open surgery in this fragile kidney transplant population.

Herein, we describe our multicenter case series and surgical video of robot-assisted ureteral reconstruction options in kidney transplant patients with ureteral stenosis.

2. Patients and methods

We treated 29 renal transplant patients suffering from ureteral stenosis. Patient and stricture characteristics are specified in Table 1. Given the complex anatomy and/or failed first endoscopic treatments, ureteral reconstruction was indicated in all cases.

All surgeries were performed at three referral centers by five surgeons from November 2019 to March 2024. All surgeons were well-experienced robotic surgeons, both with or without extensive experience in robot-assisted kidney transplantation. The Da Vinci Xi (Intuitive Surgical, Sunnyvale, CA, USA) robotic system was used in all cases, as well as an AirSeal insufflator (ConMed Corp, Utica, NY, USA) to achieve low-pressure pneumoperitoneum (8 mmHg). The patients were positioned in dorsal decubitus. Trocars were placed linearly (camera port supraumbilical and fourth arm on the contralateral kidney transplant side) and one (Ghent, Belgium) or two (Turin, Italy) assistant ports were used.

All patients had a preoperative JJ stent and/or nephrostomy tube. As each case had a unique indication and anatomy, six different surgical approaches were used, as presented in the video and shown with surgical description in Fig. 1: ureteroneocystostomy with (n = 2; Ghent, Belgium) or without (n = 4; Turin, Italy) a Lich-Gregoir antireflux tunnel, ureteroneocystostomy with a Boari flap (n = 3), ureteroureterostomy (n = 1), and pyeloureterostomy using the ipsilateral (n = 18) or contralateral (n = 1) native ureter.

Table 1 – Patient and disease characteristics

Characteristic	Value
Sex, *n* (%)	
M	20 (69)
F	9 (31)
Age at surgery (yr), median (IQR)	57 (49–64)
BMI (kg/m^2), median (IQR)	26.9 (23.2–29.9)
Donor type, *n* (%)	
Deceased donor	27 (93)
Living donor	2 (7)
Primary transplant approach (open surgery), *n* (%)	29 (100)
Site of stricture, *n* (%)	
Proximal	10 (34)
Distal/anastomosis	10 (34)
Pan-ureteral	9 (31)
Length of stricture, *n* (%)	
<1 cm	4 (14)
1–3 cm	10 (34)
>3 cm	15 (52)
GFR in acute setting (ml/min), median (IQR)	30 (21–39)
Acute treatment, *n* (%)	
JJ stent	5 (17)
Nephrostomy	19 (66)
JJ stent + nephrostomy	5 (17)
Timing of acute treatment after transplantation (mo), median (IQR)	4 (2–46)
GFR after desobstruction (ml/min), median (IQR)	45 (31–60)
Endoscopic treatment before reconstruction	3 (10%) balloon dilation

BMI = body mass index; F = female; GFR = glomerular filtration rate; IQR = interquartile range; M = male.

In Fig. 2, we present a decision-making flowchart of the techniques used in this series.

All patients received a JJ stent during reconstructive surgery. Intravenous indocyanine green (ICG) and the Firefly near-infrared system may be used to evaluate ureteral vascularization. Patients were followed postoperatively with transplant kidney ultrasound, and renal function was monitored.

3. Results

All surgeries were completed successfully without intraoperative complications.

The median glomerular filtration rates (GFRs) in the acute setting (before kidney drainage) and preoperatively (after the placement of a JJ stent and/or nephrostomy) were 30 (IQR 21–39) and 45 (IQR 31–60) ml/min, respectively. The postoperative GFRs were 47 (IQR 30–62) ml/min at 1 mo, 46 (IQR 31–58) ml/min at 3 mo (n = 28), 45 (IQR 31–73) ml/min at 6 mo (n = 26), 41 (IQR 33–69) ml/min at 12 mo (n = 23), 36 (IQR 28–60) ml/min at 2 yr (n = 12), 30 (IQR 27–47) ml/min at 3 yr (n = 6), and 35 (IQR 25–44) ml/min at 4 yr (n = 3).

The median surgical time was 208 (IQR 174–244) min. The median hospital stay was 4 (IQR 3–6) d. If the patient had a preoperative nephrostomy tube (n = 24), it was removed either on postoperative day 2 or on postoperative day 5 pending absence of leakage at pyelogram, according to the centers' preference (median 2 [IQR 1–5] d). JJ stents were removed after 28 d (median, IQR 20–41 d).

Postoperative complications were limited. One patient (3%) had urosepsis due to JJ stent dislocation on the 7th postoperative day, requiring immediate stent replacement and treatment in the intensive care unit (Clavien-Dindo grade 4). Within 90 d, two patients (7%) were diagnosed with recurrent hydronephrosis and acute kidney function deterioration (Clavien-Dindo grade 3b), needing to reposition a JJ stent (one of these required chronic JJ stenting). Four patients (14%) needed antibiotics for transplant pyelonephritis (three patients with a postoperative JJ stent still in place and one patient 1 wk after stent removal; Clavien-Dindo grade 2). One patient (3%) needed antibiotics for pneumonia and one patient (3%) for infection of unknown origin (both Clavien-Dindo grade 2). No surgery-related complications occurred after 90 d. Of 29 patients, 28 (97%) were free from nephrostomy or a JJ stent at a median follow-up of 18 (IQR 13–34) mo.

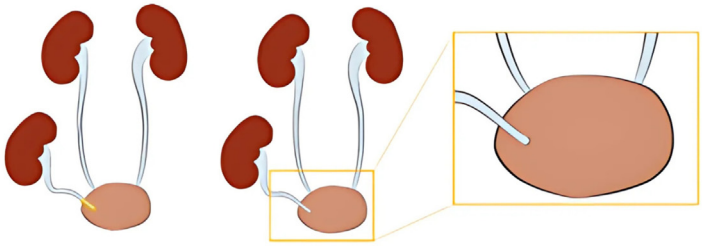
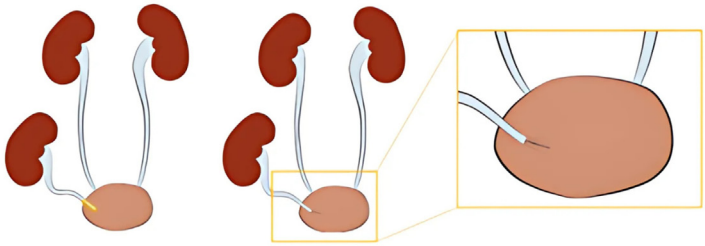
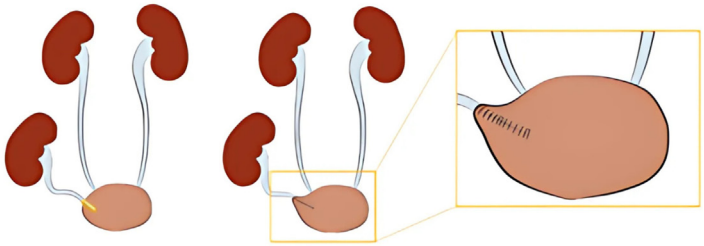
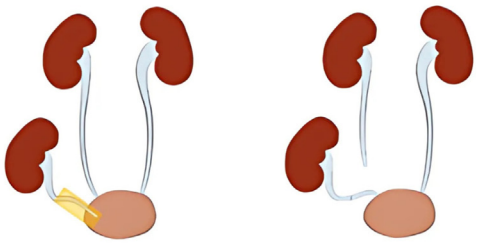
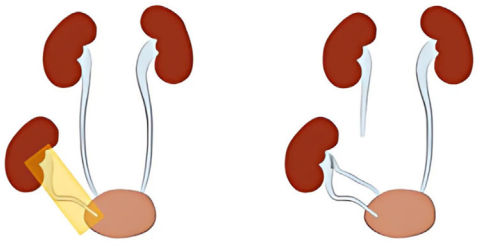
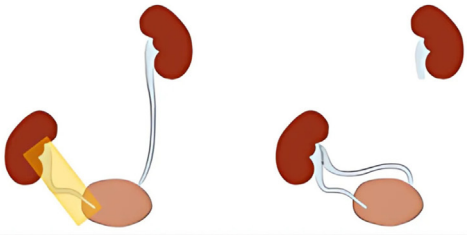
4. Discussion

The robotic approach for the treatment of post-transplant ureteral complications is not adopted widely. However, it may offer several technical benefits to help overcome inherent tissue-related problems, such as scar tissue formation and poor blood supply, often present in these complex cases. This includes a magnified three-dimensional vision, precise suturing, great dexterity in small anatomic spaces, high-quality anastomosis, fluorescence imaging with ICG to check vascular supply, and a robotic ultrasound transducer to identify the graft pyelum and hilar vessels. The latter is especially important for selecting the best incision spot of the graft pelvis, avoiding injury to major graft vessels. In addition, general advantages of robotic surgery such as shorter hospitalization, quicker recovery, and shorter learning curves may apply in these cases. Therefore, in the study period, a robotic approach was always considered the preferred treatment strategy over an open approach.

Robot-assisted transplant ureteral reconstruction has been described as technically feasible in small case series, all concluding that it may provide an effective and minimally invasive alternative in the treatment of this complex surgical problem [3–7]. Of these studies, however, we report the largest patient sample (29 compared to three to ten patients). In contrast with previous studies, we did not have any conversions to an open approach. One case report proved that the use of the robotic approach was feasible, but addressed the difficulty of identifying the graft ureter and dealing with local fibrosis, which may be easier using an open approach [8]. In our opinion, the multiple advantages of a robotic approach can overcome this problem, particularly the intraoperative use of Firefly fluorescence imaging and/or a robotic ultrasound transducer and/or three-dimensional reconstructions; the latter two can be consulted in the console through the TilePro function. Firefly fluorescence imaging can be used to (1) identify the ureter and/or renal pelvis after an antegrade injection of ICG through the nephrostomy tube or a retrograde injection through the bladder catheter in case of a double-J ureteral catheter, (2) identify major arteries and veins, and/or (3) assess vascular supply of the tissues to be reconstructed after an intravenous injection of ICG. The robotic ultrasound transducer is particularly interesting for (1) identifying the renal pelvis and ureter after injecting saline solution through the nephrostomy tube or bladder catheter, and (2) identifying major vascular structures. Identification of the graft ureter can remain challenging. Therefore, in addition to the aforementioned technical advantages of the robotic platform, we strongly recommend the study of a preoperative computed tomography scan to identify anatomical landmarks where the ureter crosses, for example, vas deferens, umbilical ligament, iliac vessels, gonadal vessels, etc. Furthermore, initiating the dissection distally under ultrasound guidance and subsequently tracing the ureter proximally are advocated in the presence of extensive fibrosis. In case a pyeloureterostomy is anticipated, the fibrotic transplant ureter actually does not need to be dissected, and all tips and tricks mentioned above can be used to focus on finding the renal pelvis.

Notably, no patient suffered from urinary leakage after reintervention. This may be because suture failure and necrosis—known as two main factors causing urinary leakage—were prevented by meticulously preserving vascular supply, vascularization control with intravenous ICG, and high-quality suturing using a robotic approach.

Additionally, no patient experienced complications of the ipsilateral native kidney after ureteral clipping. Albeit a point of debate, a native nephrectomy was never performed, as multiple series and our own experience have shown very low complication rates after ligating the native

a Uretero-neo-cystostomy	
b Uretero-neo-cystostomy with Lich-Gregoir anti-reflux tunnel	
c Uretero-neo-cystostomy with Boari-flap	
d Uretero-ureterostomy	
e Pyelo-ureterostomy ipsilateral	
f Pyelo-ureterostomy contralateral	

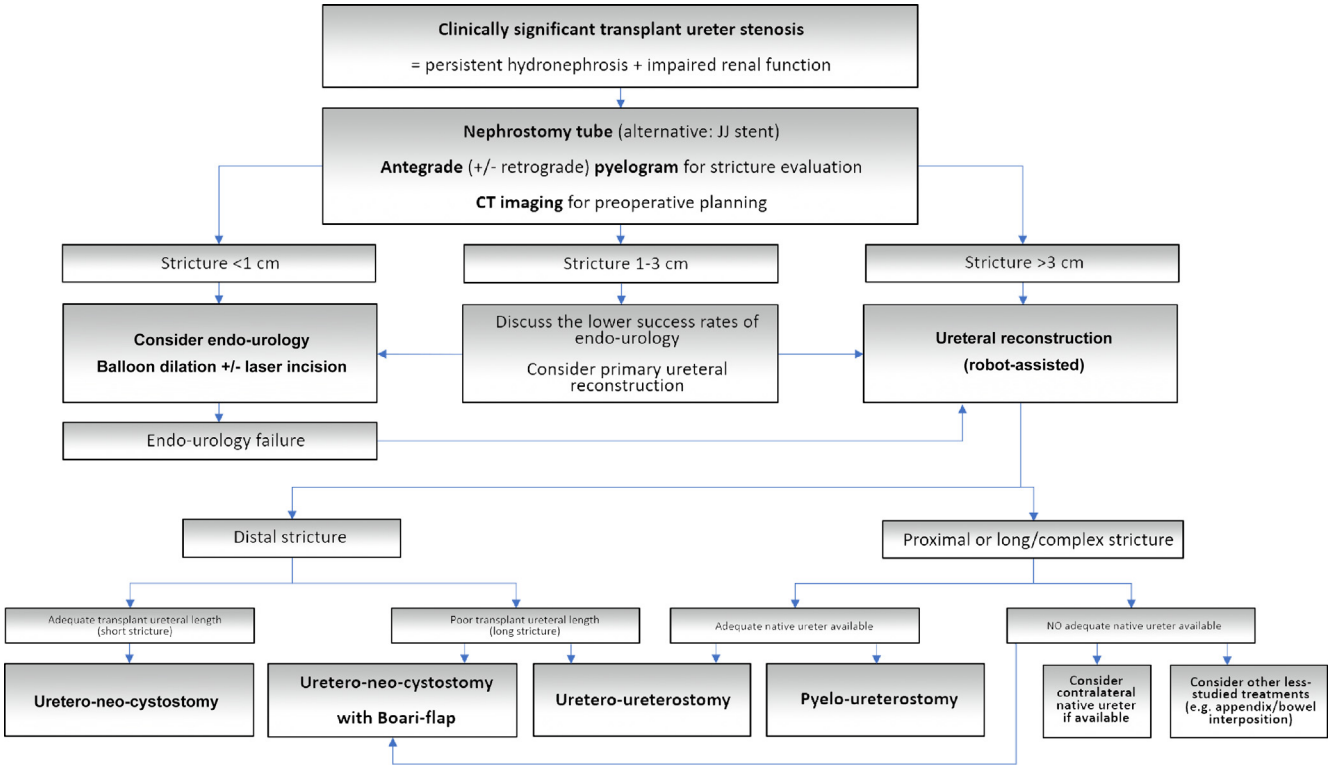


Fig. 2 – Proposed flowchart for the decision-making process for the treatment of clinically significant transplant ureter stenosis. CT = computed tomography.

ureter without nephrectomy (if no extensive infectious history) [9].

Depending on the size and location of the stricture, recurrence rates increase significantly after endourological management and surgical revision is often needed [10]. Arpali et al [11] reported an endoscopic success rate of 24%, compared with an open intervention success rate of 81% [11]. Similar results are found in other comparative series, with success rates of reconstructive techniques of up to 92% [12]. Systematic reviews performed by Caamiña et al [10] and Kwong et al [13] showed an initial endoscopic success rate of around 60%, with best results in shorter strictures, severely stressing patient selection. The EAU guidelines recommend upfront reconstruction for all strictures >3 cm, nonetheless reporting a limited endoscopic success rate of <50% in strictures >1 cm [1]. In the latter group, success rates for ureteral reconstruction are much higher. Therefore, we opt for these techniques for strictures of 1 cm or longer. Location, length of the stricture, and condition of the remaining ureter following excision dictated the choice for a specific technique of reconstruction, as illustrated in Fig. 1. In Fig. 2, we propose a treatment decision flowchart based on stricture properties.

Fig. 1 – Stepwise illustrations of different ureteral reconstruction techniques with stricture site marked in yellow (©2024 Louis Ryckembusch, Intuitive Surgical Operations, Inc.): (A) Ureteroneocystostomy without an antireflux tunnel (indication = short and distal strictures). After isolating the transplant ureter and making a transverse opening in the bladder, a tension-free ureteroneocystostomy is performed using a PDS 5-0 suture (Ethicon Inc, Johnson & Johnson Corp, Cincinnati, OH, USA). (B) Ureteroneocystostomy with a Lich-Gregoir antireflux tunnel (indication = short and distal strictures, with or without accompanying reflux). Additionally to the above-mentioned technique, an antireflux tunnel can be created to prevent possible future infections and according to the EAU (primary) renal transplant guidelines [1]. After locating and disconnecting the transplant ureter, the initial vesicoureteral junction is sutured. According to the Lich-Gregoir technique, a Y-shaped detrusorotomy is performed and the bladder mucosa is incised at the medial edge. The transplant ureter is connected to the bladder using a PDS 5-0 suture. The detrusorotomy is closed to create a submucosal antireflux tunnel using V-Loc 3-0 (Medtronic, Minneapolis, MN, USA). In this series, the creation of an antireflux tunnel was purely center specific (performed in Ghent, Belgium). (C) Ureteroneocystostomy using a Boari flap (indication = long distal stricture without the possibility of a tension-free anastomosis or midureteral/proximal stricture with unavailability of native ureter). After locating and disconnecting the transplant ureter, the stenotic segment is excised and the remaining ureter is spatulated. A bladder flap is created on the anterolateral bladder wall, long enough to reach the transplant ureter. A tension-free anastomosis is performed between the spatulated ureter and the bladder flap using a PDS 5-0 suture. The bladder flap is tubularized completely. (D) Ureteroureterostomy using a native ureter (indication = distal or long/complex strictures with adequate ureteral length and quality available). After locating the transplant ureter, it is transected proximal to the stricture. The native distal ureter is isolated, clipped proximally, and transected. Both ureteral ends are spatulated. The anastomosis is performed using a running PDS 5-0 suture. (E) Pyeloureterostomy using an ipsilateral native ureter (indication = proximal or long/complex strictures). The transplant kidney and native ipsilateral ureter are located. The native ureter is clipped proximally and transected. The transplant renal pelvis is located by filling through the nephrostomy tube and guided by intraoperative ultrasound through the TilePro function using the robotic transducer (BK Medical Holding, Burlington, MA, USA). The renal pelvis is then incised and the native ureter is spatulated. Anastomosis is performed using a PDS 5-0 suture. (F) Pyeloureterostomy using a contralateral native ureter (indication = proximal or long/complex strictures; ipsilateral native ureter not available). One patient presented with complete necrosis of the transplant ureter and ipsilateral renal agenesis. Consequently, the contralateral native ureter was used for a pyeloureterostomy. The right native ureter is dissected and mobilized without compromising its vascular supply. The ureter was already clipped proximally following a previous nephrectomy. The transplant kidney's pelvis on the left is located by filling through the nephrostomy tube and guided by intraoperative ultrasound through the TilePro function using the robotic transducer. The right ureter is tunneled to the left fossa under the sigmoid meso. The renal pelvis is incised and the anastomosis is performed using a PDS 5-0 suture. EAU = European Association of Urology.

Despite the high success rate of open reintervention, this requires significant abdominal wall incisions, usually reiterating the same access used for the transplant. Not surprisingly, an overall complication rate of up to 53% and a high-grade complication rate (Clavien-Dindo $\geq$3) of up to 28% [12,14] have been reported. Endoscopic treatment is also associated with a certain degree of morbidity, with an overall 9% and an only 2% high-grade complication rate in a recent series by Territo et al [15]. In a systematic review by Kwong et al [13], endoscopic management was even more complicated than surgical reconstruction. Findings from our series showing a high-grade complication rate of 10% in the first 90 d and 0% long-term overall complications suggest that the robotic approach may combine the effectiveness of open surgery and the low-risk profile of endourological management.

The main limitations of our study include the relatively small sample size, in spite of being the largest series reported to date, the relatively short median follow-up time, and some degree of interinstitutional variation in perioperative management (eg, hospitalization time and postoperative derivation management), possibly distorting results. Furthermore, our retrospective findings advocate confirmation through prospective data.

5. Conclusions

Robot-assisted management of ureteral stenosis in kidney transplant patients is safe and feasible. With a success rate of 97%, it allows for effective restoration of a functioning urinary tract. This is associated with quick recovery, a low complication rate, and preserved renal function in a known fragile patient population. We also provide a surgical video showing several different ureteral reconstruction techniques performed with a robot-assisted approach. These techniques have unique indications according to the type of stricture and should preferably be handled by surgeons with elaborate experience in renal transplantation and robotic surgery.

***Author contributions*:** Joris Vangeneugden had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Vangeneugden, Van Praet, Decaestecker, Gontero.
Acquisition of data: Vangeneugden, Lavagno, Van Praet, Decaestecker, Gontero.
Analysis and interpretation of data: Vangeneugden, Lavagno.
Drafting of the manuscript: Vangeneugden.
Critical revision of the manuscript for important intellectual content: Lavagno, Berquin, Desender, Van Laecke, Oderda, Allasia, Van Praet, Breda, Decaestecker, Gontero.
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Appendix A. Supplementary material

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