Long-term outcomes of catheterizable continent urinary channels: what do you use, where you put it and does it matter?

Konrad M. Szymanski, , Benjamin Whittam, Rosalia Misseri, Chandra K. Flack, Katherine C. Hubert, Martin Kaefer, Richard C. Rink, Mark P. Cain

Runninghead: Long-term outcomes of catheterizable urinary channels

Keywords: urinary bladder, intermittent urethral catheterization, appendix, ileum, urinary diversion, postoperative complications

Acronyms: APV (appendicovesicostomy)

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Summary

Introduction: Appendicovesicostomy (APV) and Monti ileovesicostomy (Monti) are commonly used catheterizable channels with similar outcomes on short-term follow-up. Their relative long-term results have not been previously published.

Objective: Our goal was to assess long-term durability of APV and Monti channels in a large patient cohort.

Study design: In this retrospective cohort study, we retrospectively reviewed consecutive patients ≤21 years old undergoing APV and Monti surgery at our institution (1990-2013). We collected data on demographics, channel type, location, continence and stomal and subfascial revisions. Kaplan-Meier survival and Cox proportional hazards analysis were used.

Results: Of 510 patients meeting inclusion criteria, 214 patients had an APV and 296 had a Monti (50.5% spiral Monti). Median age at surgery was 7.4 years for APV (median follow-up: 5.7 years) and 8.7 years for Monti (follow-up: 7.7 years). Stomal stenosis, overall stomal revisions and channel continence were similar for APV and Monti ($p \geq 0.26$). Fourteen APVs (6.5%) had subfascial revisions compared to 49 Montis (16.6%, $p=0.001$). On survival analysis, subfascial revision risk at 10 years for APV was

8.6%, Monti channels excluding spiral umbilical Monti: 15.5% and spiral umbilical Monti: 32.3% ($p<0.0001$, Figure). On multivariate regression, Monti was 2.09 times more likely than APV to undergo revision ($p=0.03$). The spiral Monti to the umbilicus, in particular, was 4.23 times more likely than APV to undergo revision ($p<0.001$). Concomitant surgery, gender, age and surgery date were not significant predictors of subfascial revision ($p\geq0.17$). Stomal location was significant only for spiral Montis.

Discussion: We present the first long-term results comparing the APV and Monti channels in a large patient population. Our study has several limitations. It is a retrospective, single center series rather than a randomized controlled trial. While controlling for surgery date was a limited way of adjusting for changing surgical techniques, residual confounding by surgical technique is unlikely, as channel implantation technique was typically unrelated to channel type. Our intention was to focus on channel reoperation, which entails the highest morbidity and cost. We did not include complications managed conservatively or endoscopically. In addition, while we did not capture patients who were lost to follow-up and possibly developed complications, we attempted to control for this through survival analysis. Importantly, it is unlikely that the relative risk of subfascial complications between channel groups would change, as being lost to follow-up is probably unrelated to channel type.

Conclusions: We demonstrate, durable long-term results with the APV and Monti techniques. The risk of channel complications continues over the channel's lifetime, with no difference in stomal complications between channels. At 10 years after initial surgery, Monti channels were twice as likely to undergo a subfascial revision (1 in 6) than APV (1 in 12). The risk is even higher in for the spiral umbilical Monti (1 in 3).

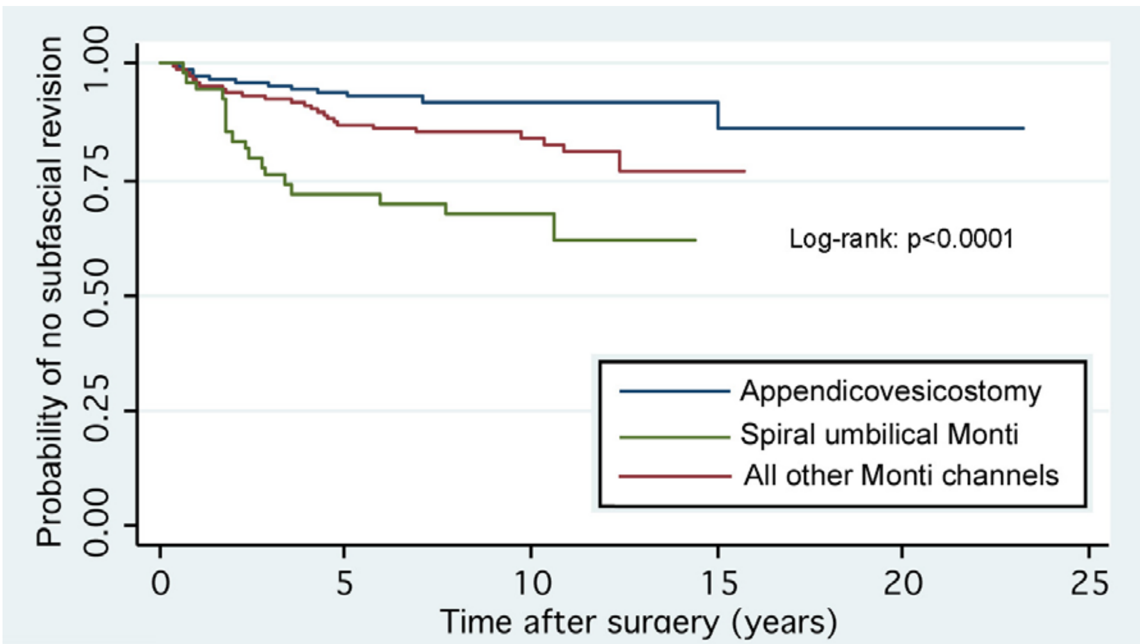

Figure. Kaplan–Meier estimates of remaining without a subfascial revision, stratified by appendicovesicostomy, spiral umbilical Monti and other Monti channels.

Abstract

Introduction: Appendicovesicostomy (APV) and Monti ileovesicostomy (Monti) are commonly used catheterizable channels with similar outcomes on short-term follow-up. Our goal was to assess long-term durability of APV and Monti channels in a large patient cohort.

Materials and Methods: We retrospectively reviewed consecutive patients ≤21 years old undergoing APV and Monti surgery at our institution (1990-2013). We collected data on demographics, channel type, location, continence and stomal and subfascial revisions. Kaplan-Meier survival and Cox proportional hazards analysis were used.

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Conclusions: We demonstrate, durable long-term results with the APV and Monti techniques. The risk of channel complications continues over the channel's lifetime, with no difference in stomal complications between channels. At 10 years after initial surgery, Monti channels were twice as likely to undergo a subfascial revision (1 in 6) than APV (1 in 12). The risk is even higher in for the spiral umbilical Monti (1 in 3).

Introduction

Since first being described in 1980, the appendix has played an integral role in the creation of continent catheterizable channels using the Mitrofanoff principle.[1] When it is not usable or available for an appendicovesicostomy (APV), other tissue may be used, particularly the transversely tubularized continent ileovesicostomy described by Yang [2] and Monti [3] (Monti), and later modified by Casale [4] (spiral Monti). We have recently reported long-term results from a large cohort of patients after a Monti procedure, noting an increased risk of subfascial revisions among spiral Monti channels to the umbilicus, likely due to a long, unsupported extravesical segment.[5]

When comparing APV and Monti techniques, at least 10 small series reported similar short-term rates of subfascial revisions.[6-15] Our initial series of urinary channels demonstrated more complications among APV than Monti channels, but the APV group had much longer follow-up.[16] Despite several decades of use, no direct comparison of long-term results of APV and Monti channels exists. The goal of this study was to assess the durability of the APV compared to the Monti channel, focusing on stomal and subfascial revisions.

Methods

Patient selection and data collection

We performed a retrospective review of consecutive patients ≤21 years old undergoing APV or Monti surgery at our institution (1990-2013). Those with continent urinary reservoirs, double Montis and channels made of tissue other than appendix or ileum were excluded. To ensure a comprehensive assessment of channel outcomes and not ignore early complications, no minimum follow-up was required. We collected data on demographics and surgery, including channel type and stomal location.

Study outcomes

Primary outcomes were subfascial and stomal revisions. Indications for reoperation were secondary outcomes. Suprafascial revisions for stomal stenosis, prolapse or granulation tissue were categorized as stomal revisions. Subfascial revisions included a laparotomy for channel angulation or diverticulum resulting in catheterization difficulties, and incontinence due to inadequate tunnel length. Among patients with multiple subfascial revisions of the same channel, time to first revision was used for analysis.

Risk factors

Given our previous work indicating that spiral Monti channels with umbilical stomas have a higher risk of subfascial revisions, [5] we compared three groups: APV, spiral umbilical Monti and all other Monti channels. Risk factors selected for the multivariate analysis included stomal location, gender, age at and date of surgery. Stomal location was categorized as umbilical or non-umbilical (right or left lower quadrants). Age at surgery was categorized into 3 clinically meaningful groups: <8 years, 8 to <16 and ≥16. To adjust for changing practices and surgical techniques, date of surgery was dichotomized as occurring within the last 10 years or before, a relatively arbitrary cutoff. While exact surgical technique details were unavailable for each case, over the last decade, channels were typically made with a 4cm submucosal tunnel in the anterior bladder wall and a V-skin flap stoma. Intravesical implantation was typically favored if the bladder was opened (i.e. concomitant bladder augmentation) and an extravesical channel was favored if it was the only procedure preformed. Channel type was dictated by surgeon preference and appendix availability.

Statistical analysis

Categorical variables were analyzed by Fisher's exact test, continuous ones by the Mann-Whitney U test. Kaplan-Meier analysis and Cox proportional hazards modeling were used, with proportional hazards assumptions verified by log-log plots and the nonzero slope test of the scaled Schoenfeld residuals. The final model did not include the diagnosis of spinal dysraphism, because it did not satisfy the proportional hazards assumption. Spinal dysraphism was not associated with the risk of a subfascial revision and the overall results did not change when it was included.

To assess changes in risk between first 5 years of follow-up and the second 5 years (5-10 years), we calculated the difference in risk at 5- and 10-year time points from the survival analysis. While other time points could be chosen, these are helpful in counseling and our previous work indicates risk may decrease after 5 years.[5] Statistical analyses were performed with a critical p=0.05 using Stata (v.10.1).

Results

Population characteristics

Of 510 patients meeting inclusion criteria, 214 patients had an APV (40.4% were split appendix, using proximal appendix for a concomitant antegrade continence enema procedure). The remaining 296 patients had a Monti, of whom half (50.5%) had a spiral Monti. The two groups had similar rates of concomitant bladder augmentation (53.7% vs. 54.7%, p=0.86) and Malone antegrade continence enema procedures (59.8% vs. 55.4%, p=0.36) (Table 1). The two groups differed in several regards. Patients undergoing an APV were less likely to have a concomitant bladder neck procedure (33.6% vs. 44.9%, p=0.01), but were more likely to be male (62.1% vs. 46.0% male, p<0.001). Median age at surgery for patients with an APV was 7.4 years (range 1.9-20.5 years) compared to 8.7 years (range 0.8-20.9 years) for a Monti (p=0.003).

Median follow-up for patients with an APV was about 2 years shorter than for a Monti (5.7 vs. 7.7 years, p=0.01). This was likely because a larger portion of APVs were performed recently, with 65.9% constructed in the last decade compared to 54.1% Monti channels (p=0.01). Patients with APV were more likely to have an umbilical stoma

(44.9% vs. 35.8%, $p=0.04$) and an underlying diagnosis other than spinal dysraphism (62.6% vs. 25.3%, $p<0.001$).

Stomal revisions

Twenty-five APVs (11.7%) underwent a stomal revision at median 1.3 years after initial channel surgery (range: 2 months-9.8 years). The most common indication was stomal stenosis (7.5% overall). Other indications included stomal prolapse (4), granulation tissue (3), channel angulation (1) or polyp (1).

Twenty-eight Montis (9.9%) underwent a stomal revision at median 1.6 years (range: 5 months-8.5 years), similar to the APV group (log-rank: $p=0.26$). The most common indication was stomal stenosis (7.4% overall), similar to APV ($p=0.99$). The remaining stomas were revised for stomal prolapse (3), granulation tissue (1), channel angulation (1) or diverticulum (1).

Subfascial revisions

Primary subfascial revision was performed in 14 patients (6.5%) with an APV at a median 2.3 years after initial channel surgery (range: 5 months-15.1 years). Most commonly, channels were revised due to difficult catheterizations secondary to channel stenosis/stricture (3.7%) and channel angulation (1.4%). Two patients (0.9%) underwent subfascial revision for channel incontinence and one (0.5%) to repair an enterovesical fistula causing difficult catheterizations.

Secondary revisions were performed in two patients (14.3% of primary revisions) for new channel incontinence at 9 months and 2.1 years after primary revision. Given two primary revisions and two secondary revisions for incontinence, continence over the lifetime of the channel was 98.1%.

Primary subfascial revision was performed in 49 patients (16.6%) with a Monti at a median of 2.3 years after the initial surgery (range: 5 months-12.4 years), which was higher than APV (p=0.001). Time to subfascial revision was similar between groups (p=0.21). Most common indications included difficult catheterizations due to channel stenosis/stricture (4.1%), channel angulation (8.4%) and channel diverticulum (0.3%). Others underwent surgery for incontinence (3.4%) and channel perforation (0.7%).

There were 6 secondary revisions (12.8% of primary revisions) for incontinence (3), channel angulation (2), and channel diverticulum (1) at a median 3.5 years after primary subfascial revision (range: 7 months-8.6 years). Given 10 incontinent channels (9 primary revisions, 2 secondary revisions for recurrent incontinence, 1 secondary revision for new incontinence), continence over the lifetime of the channel was 96.6%. This was statistically indistinguishable from the APV (p=0.41). No channel underwent a third revision.

<u>Risk of subfascial revision by channel type</u>

Stratifying channels by stomal location, the proportion of channels undergoing subfascial revision ranged from 5.1% to 32.1% (Table 2). After correcting for differential follow-up time, the risk of subfascial revision was significantly different between channel groups (log-rank: p=0.0006, Figure 1a). The risk of subfascial revision was indistinguishable between the umbilical and non-umbilical APV (log-rank: p=0.44), and APV channels made from split appendix versus an entire appendix (log-rank: p=0.31).

Compared to non-umbilical APV, spiral umbilical Monti channels had a higher revision risk (log-rank: p<0.001). Spiral and traditional Monti channels with non-umbilical stomas also had higher revision risk (log-rank: p≤0.04) than non-umbilical APV. Although traditional umbilical Monti channels clustered with other Monti channels on Kaplan-Meier plots, they did not reach statistical significance compared to the non-umbilical APV (log-rank: p=0.12). Since this was the smallest group with the fewest subfascial revisions, the log-rank test was likely underpowered to detect a difference. These results confirmed our intention to analyze channels in three groups for subsequent analysis: APV, spiral umbilical Monti and all other Monti channels.

Comparing the three groups, the risk of subfascial revision was lowest in the APV, highest in spiral umbilical Monti and intermediate in all other Monti channels (log-rank: p<0.001) (Figure 1b). For the APV, 6.4% and 8.6% of channels underwent a subfascial revision at 5 and 10 years after surgery, respectively (Table 3). For the umbilical spiral Montis, 27.9% and 32.3% underwent a subfascial revision at 5 and 10 years, respectively. For all other Monti channels, 12.9% and 15.5% underwent a subfascial revision at 5 and 10 years, respectively.

Timing of subfascial revisions

In terms of timing of revisions, 78.6% of APV revisions occurred in the first 5 years, compared to 83.3% for spiral umbilical Montis and 80.6% for all other Montis. Using survival analysis data for each group, we calculated the change in risk of revision in the first and second 5 years of follow-up. The risk of subfascial revision continued to increase between years 5-10 for each of the groups (by +2.2% to +4.4%), but this increase was consistently smaller than the risk observed during years 0-5 (+6.4% to +27.9%).

Risk factors of subfascial revision

On univariate Cox proportional hazards regression, overall stomal location, concomitant surgeries, gender, age at surgery and surgery within the past 10 years were not associated with increased risk of subfascial revision ($p \geq 0.10$) (Table 3). Compared to the APV, spiral umbilical Monti had a 4.58-fold increased risk of revision ($p<0.001$) and all other Monti channels had a 1.95-fold increased risk ($p=0.04$). These associations persisted on multivariate analysis when controlling for overall stomal location, concomitant surgeries, gender, age and date of surgery (spiral umbilical Monti: HR 4.23, $p<0.001$, all other Monti channels: HR 2.09, $p=0.03$). No other variables were associated with the risk of subfascial revision on multivariate regression ($p \geq 0.17$).

Discussion

Based on a large cohort of patients with catheterizable urinary channels constructed in childhood and adolescence, we report long-term channel durability and excellent channel continence of 96-98%, which is consistent with our previous series and those of others.[7, 11, 12, 14, 17-23] We found a persistent, but decreasing, risk of requiring a subfascial revision over the lifetime of the channel. The risk of subfascial revisions is doubled for Monti compared to APV, with a quadrupling of risk for the spiral umbilical Monti. Finally, concomitant surgeries were not associated with increased subfascial revision risk.

Our findings support that the appendix, rather than reconfigured small bowel, is a preferred urinary catheterizable channel, not only because it avoids a bowel anastomosis, but also because of increased durability. The absence of longitudinal suture lines, a naturally-occurring lumen and a mesentery spread over a longer portion of the channel may make the APV less predisposed to ischemia and trauma. Trauma from recurrent catheterizations may result in an unsupported, elongated extravesical portion of the channel or a channel diverticulum. Narayanaswamy *et al.* reported channel diverticula exclusively in a quarter of mostly double Monti channels, with one third requiring a revision, and none in an APV.[19] Indeed, the only two patients in our study who developed a channel diverticulum had Monti channels. Channel angulation and diverticulum were indications for 53% of primary Monti revisions vs. 21% of APV revisions.

Three previous studies suggested Monti channels have a higher risk of complications than APV. Although one series reported that 25 Monti channels had more catheterization problems than 69 APVs (60% vs. 26%), the overall risk of surgical intervention overall was similar at 3 years.[19] Weikert *et al.* noted a possible trend toward higher channel-related complications in 12 spiral umbilical Montis compared to 55 APV at 1.5 years.[24] A report comparing 37 APV to 7 non-APV (2 Monti) found that non-APV channels had more difficulties with catheterizations, most commonly due to excessive extravesical length.[17]

We identified 10 series reporting rates of complications and reoperations in APV and Monti channels to be similar.[6-15] Our initial report of short-term outcomes of 100 catheterizable channels noted higher complications in APV than Monti (21% vs. 10%), but the APV group had longer follow-up (2.5 vs. 0.8 years).[16] Similar to our initial report, previous studies presented short-term results at median follow-up of 2-4 years in a small number of channels, particularly Monti channels, and did not correct for differential follow-up time. They were likely underpowered to detect differences between relatively rare outcomes. In addition, some authors analyzed urinary and bowel channels together,[6, 7] while others grouped all complications, regardless if managed non-operatively or by endoscopic, stomal and subfascial interventions.[10, 15, 16]

Our finding that umbilical stomas are associated with an increased revision risk in the typically longer, spiral Monti, but not the APV or traditional Monti, suggests that it may be channel length, rather than stomal location, which predisposes to complications. These findings are consistent with our previous reports on Monti channels[5, 25] and four other studies on catheterizable channels.[10, 11, 17, 20] This reinforces that the ideal channel is straight, short, supple and well supported.

While we agree that most channel complications occur early,[8, 10, 20] they can occur throughout the channel lifetime. The last revision in our study occurred at 15.1 years. Survival curves do not appear to diverge for several years after surgery, suggesting that, after initial healing complications, subsequent problems may be due to channel "wear and tear"[10] or changes in body habitus.

Our study has several limitations. While it represents practices of seven experienced pediatric urologists over 24 years, it remains a retrospective, single center series rather than a randomized controlled trial. While controlling for surgery date was a limited way of adjusting for changing surgical techniques, residual confounding by surgical technique is unlikely, as channel implantation technique was typically unrelated to channel type. As our results originate from a high-volume center, they may not be generalizable to other clinical settings. We did not assess obesity as a potential risk factor for channel complications and this will be a the focus of future work. Our findings also underestimate overall channel complication risk. Our intention was to focus on channel reoperation, which entails the highest morbidity and cost. We did not include complications managed conservatively or endoscopically. Between a third to half of cases of stomal stenosis [11, 12, 14, 15, 19, 20] or difficult catheterizations [23] can be managed conservatively. One group successfully managed 82% of channel complications with endoscopic or stomal procedures.[8] In addition, we did not capture patients who were lost to follow-up and possibly developed complications. While the absolute risk of subfascial complications may possibly change if those patients were included, we attempted to control for this through survival analysis. Importantly, it is unlikely that the relative risk of subfascial complications between channel groups would change, as being lost to follow-up is probably unrelated to channel type.

Conclusions

We showed durable, long-term results with APV and Monti techniques. The risk of channel complications continues over the channel's lifetime, with a marked reduction after 5 years of follow-up. There was no difference in stomal complications between channels. At 10 years after initial surgery, Monti channels were twice as likely to undergo a subfascial revision (1 in 6) than APV (1 in 12). The risk is even higher in for the spiral umbilical Monti (1 in 3).

Acknowledgements

None

Conflicts of interest

None

Research support

None

Internal Review Board approval

Approved (IRB 0908-70)

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Tables

Variable	**Appendicovesicostomy (n=214)**	**Monti (n=296)**	**p-value**
Male gender	133 (62.1%)	136 (46.0%)	<0.001
Caucasian race	189 (88.3%)	273 (92.2%)	0.17
Age at surgery (years)			
<8 years old	122 (57.0%)	134 (45.3%)	0.03
8 to <16 years old	71 (33.2%)	128 (43.2%)	
≥16 years old	21 (9.8%)	34 (11.5%)	
Median age at surgery (years, range)	7.4 (1.9-20.5)	8.7 (0.8-20.9)	0.003
Surgery within last 10 years (≥2003)	141 (65.9%)	160 (54.1%)	0.01
Median follow-up (years, range)	5.7 (0.1-23.3)	7.7 (0.1-15.8)	0.01
Stomal location			
Umbilical stoma	96 (44.9%)	106 (35.8%)	0.04
Non-umbilical stoma	118 (55.1%)	190 (64.2%)	
Right lower quadrant	113 (52.8%)	183 (61.8%)	
Left lower quadrant	5 (2.3%)	7 (2.4%)	
Concomitant surgeries			
Bladder augmentation	115 (53.7%)	162 (54.7%)	0.86
Bladder neck procedure	72 (33.6%)	133 (44.9%)	0.01
Bladder neck sling	25 (11.7%)	84 (28.4%)	
Bladder neck reconstruction	47 (22.0%)	73 (24.7%)	
Bladder neck closure	4 (1.9%)	4 (1.4%)	
Artificial urinary sphincter	0 (0.0%)	2 (0.7%)	
Malone antegrade continent enema	128 (59.8%)	164 (55.4%)	0.36
Underlying diagnosis			
Myelodysplasia (lipo/myelomeningocele)	80 (37.4%)	221 (74.7%)	<0.001
Sacral agenesis	4	10	
Other spinal dysraphism	7	6	
Trauma	14	12	
Oncologic	2	3	
Exstrophy-epispadias	36	6	
Cloacal exstrophy	2	10	
Cloaca/urogenital sinus	10	6	
Posterior urethral valves	20	3	
Imperforate anus	6	9	
Non-neurogenic neurogenic bladder	12	0	
Cerebral palsy	6	4	
Other	15	6	

Table 1. Patient characteristics.

Channel type and stomal location	**Number**	**Number of first subfascial revisions**	**P-value**	**Median follow-up (years)**
Appendicovesicostomy				
Non-umbilical	118	6 (5.1%)	reference	5.4
Umbilical	96	8 (8.3%)	0.41	6.2
Monti				
Traditional				
Non-umbilical	96	14 (14.6%)	0.03	8.4
Umbilical	50	6 (12.0%)	0.19	9.9
Spiral				
Non-umbilical	94	11 (11.7%)	0.13	4.8
Umbilical	56	18 (32.1%)	<0.001	9.0

Table 2. Subfascial revisions stratified by channel type and stomal location (Fisher's exact test).

Channel type	**At 5 years**	**At 10 years**
Appendicovesicostomy	6.4%	8.6%
All other Monti channels	12.9%	15.5%
Spiral umbilical Monti	27.9%	32.3%

Table 3. Risk of subfascial revision.

Variable	**Univariate**		**Multivariate**	
	HR (95% CI)	**p-value**	**HR (95% CI)**	**p-value**
Channel type				
Appendicovesicostomy	1.00 (reference)	n/a	1.00 (reference)	n/a
All other Monti channels	1.95 (1.03-3.69)	0.04	2.09 (1.07-4.07)	0.03
Spiral umbilical Monti channel	4.58 (1.26-9.27)	<0.001	4.23 (1.91-9.37)	<0.001
Umbilical vs. non-umbilical stoma	1.39 (0.85-2.28)	0.19	1.14 (0.60-2.27)	0.72
Concomitant surgeries				
Bladder augmentation	1.30 (0.78-2.18)	0.32	1.32 (0.78-2.23)	0.30
Bladder neck procedure	1.52 (0.93-2.50)	0.10	1.36 (0.81-2.28)	0.25
Malone antegrade continence enema	0.80 (0.49-1.31)	0.38	0.78 (0.47-1.30)	0.34
Male vs. female	1.09 (0.66-1.78)	0.74	1.14 (0.68-2.02)	0.62
Age at surgery				
<8 years old	1.18 (0.69-2.03)	0.55	1.17 (0.68-2.02)	0.58
8 to <16 years old	1.00 (reference)	n/a	1.00 (reference)	n/a
≥16 years old	1.80 (0.83-3.91)	0.14	1.77 (0.79-3.86)	0.17
Surgery within last 10 years vs. earlier	1.06 (0.62-1.79)	0.84	1.46 (0.82-2.58)	0.20

Table 4. Risk factors for subfascial revision (HR: hazard ratio).

Figures

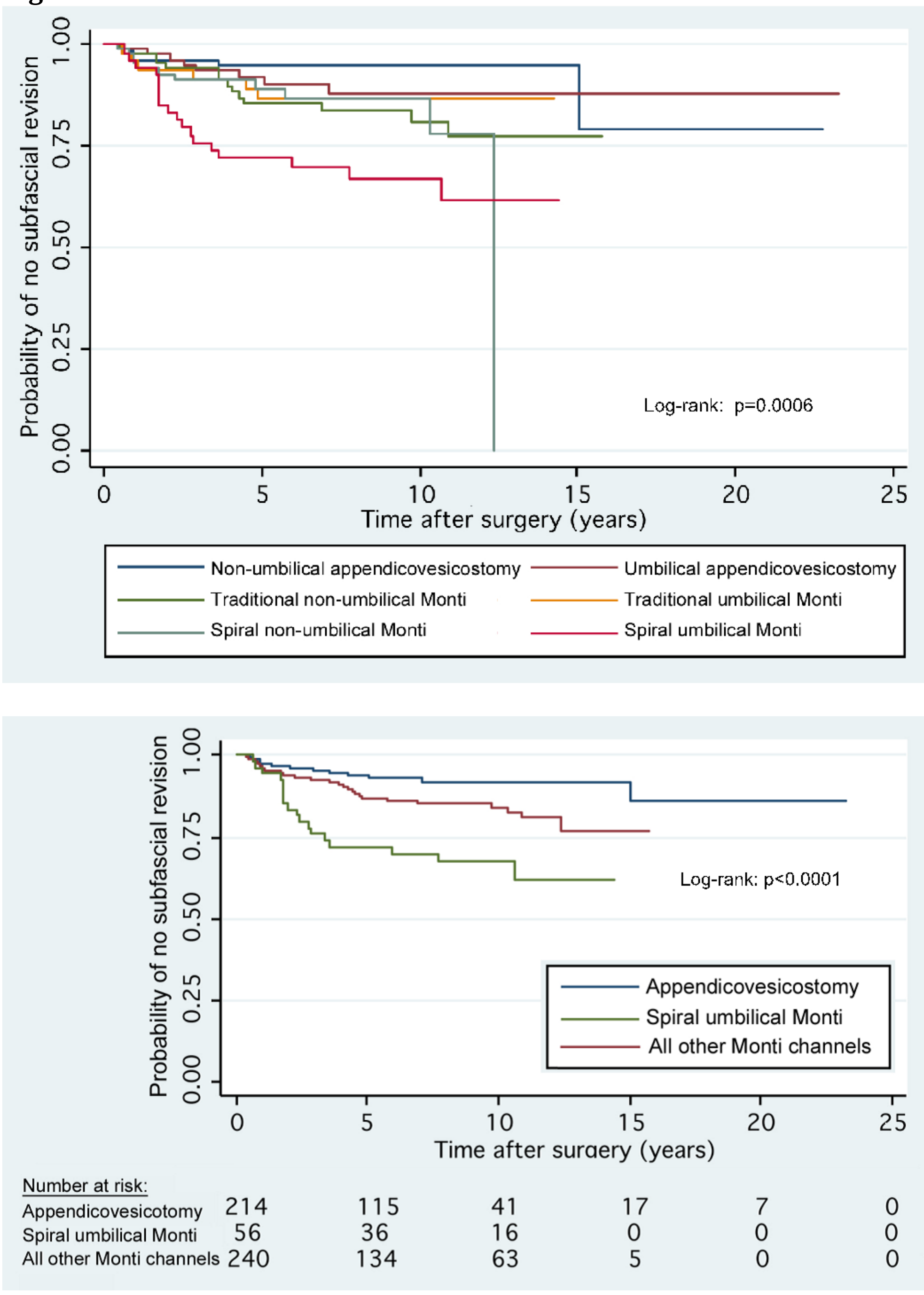

Figure 1. Kaplan–Meier estimates of remaining without a subfascial revision, a) stratified by channel type and stomal location, and b) stratified by appendicovesicostomy, spiral umbilical Monti and other Monti channels.