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ORIGINAL ARTICLE

Cost analysis of single-incision versus conventional laparoscopic surgery for colon cancer: A propensity score-matching analysis☆

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Summary *Background/objective:* Although many studies have demonstrated similar perioperative outcomes for single-incision laparoscopic surgery (SILS) and conventional laparoscopic surgery (CLS) for colon cancer, few have directly compared the costs of them. We aimed to compare costs between SILS and CLS for colon cancer.
Methods: We analyzed the clinical outcomes and overall hospital costs of patients who underwent laparoscopic surgery for colon cancer from July 2009 to September 2014 at our institution; 288 were used for analysis after propensity score matching. The total hospital charge, including fees for the operation, anesthesia, preoperative diagnosis, and postoperative management was analyzed.
Results: The total hospital charges were similar in both groups ($8770.40 vs. $8352.80, $P = 0.099$). However, the patients' total hospital bill was higher in the SILS group than in the CLS group ($4184.82 vs. $3735.00, $P < 0.001$) mainly due to the difference of the cost of access devices. There was no difference in the additional costs associated with readmission due to late complications between the two groups ($2383.08 vs. $2288.33, $P = 0.662$). Incremental cost-effectiveness ratio for total incision length in 'total hospital charge' and patient's bill and government's bill in 'cost of instruments and supplies' were -$107.08/1 cm, -$109.70/1 cm, and $80.64/1 cm, respectively.

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Conclusion: SILS for colon cancer yielded similar costs as well as perioperative and long-term outcomes compared with CLS. Therefore, SILS can be considered a reasonable treatment option for colon cancer for selective patients.

1. Introduction

Minimally invasive surgery (MIS), including laparoscopic surgery (LS) and robotic surgery, has shown to have acceptable short- and long-term outcomes in the context of various diseases.[1–3] LS is an option for colorectal cancer based on the similar or even superior results associated with the procedure compared with those of open surgery for colorectal malignancies.[4–6] Novel techniques, such as natural orifice transluminal endoscopic surgery or single-incision laparoscopic surgery (SILS), have been developed to meet surgeons' efforts to maximize the advantages of MIS and the patients' desires to reduce scarring and pain.

SILS, which is characterized by only one surgical incision, has been suggested as an option for treating colorectal malignancies. SILS for colon cancer has shown comparable oncologic outcomes, as well as a shorter total incision length, when compared with conventional laparoscopic surgery (CLS).[7–10] However, it has several limitations as an alternative treatment option for colorectal cancer, including patient selections, technical difficulties, and questionable cost-effectiveness.[11,12]

Therefore, recent studies of SILS for colorectal cancer have attempted to clarify the learning curve for both LS-experienced surgeons and novices, to expand the indications for SILS, and more comfortable technical tips, whereas prior studies have primarily focused on the safety and feasibility of the procedure.[13,14] However, to date there has been no cost-effectiveness study of SILS for colon cancer, and only a few studies having reported the costs associated with the procedure. The aim of the current study was to focus on the comparative costs of SILS versus CLS for colon cancer. We compared the costs of SILS with those of CLS, subdividing the total hospital charges into five categories.

2. Methods

2.1. Patients

We retrospectively reviewed the medical records of the patients who underwent SILS and CLS for colon cancer at Severance Hospital, Yonsei University College of Medicine, Seoul, Korea between July 2009 and September 2014. The institutional review board approved the study before the clinical data collection was performed. All patients signed an informed consent form after receiving information regarding both surgical methods from their surgeon, including the possibility of a difference in costs. The colon was defined as the large intestine from the cecum to the rectosigmoid junction; those patients with rectal cancer were excluded from this study. Patients with synchronous or recurrent colon cancer and patients who received emergency surgery for perforation, obstruction, or bleeding were also excluded.

Two surgeons with experience in CLS performed SILS and CLS, and two additional surgeons performed CLS only. SILS required only one surgical incision using an Octo™ port (Dalim Medical, Seoul, Korea), whereas CLS necessitated three or four incisions and a minilaparotomy to retrieve the colon. All surgeons used one energy device and two or three linear or circular staplers, according to the type of surgery performed (anterior resection or right hemicolectomy). The length of incision was calculated by the sum of all incision lengths. Details of these surgical techniques are described in our previous reports.[10,15] The patients' baseline characteristics and perioperative outcomes were compared between the two groups. Postoperative complications were considered early when they occurred within 30 days of surgery, and late when they occurred between 30 days after the surgery to February 2018, the final follow-up date. The additional costs due to early complications were included in the hospitalization and analyzed, whereas the additional costs incurred by late complications were analyzed separately.

2.2. Costs

The total hospital charges in this study were composed of fees for the operation, anesthesia, preoperative diagnosis, postoperative management, and other costs (Fig. 1). Each of these costs was divided into insured charges (ICs) and noninsured charges (NICs), in accordance with the reimbursement scheme of the Korean National Health Insurance Corporation (NHIC), a government organization. During the study period, the NHIC paid 95% of all ICs for patients who had a malignancy for 5 years from their date of diagnosis; this was the government's bill. The patient's bill in this study was therefore the sum of 5% of the ICs and 100% of the NICs.

The operation fees included the surgery and treatment fees, plus the cost of instruments and supplies. The surgery and treatment fees included the cost of surgery; the use of the operating room; compensation for the doctors and nurses who participated in the surgery; and the cost of urinary catheter insertion, aseptic dressings, nasogastric tube insertion, and other procedures. The surgery and treatment fees for SILS and CLS were the same, but the costs differed according to whether an anterior resection or right hemicolectomy was performed. The ICs associated with right hemicolectomies and anterior resections

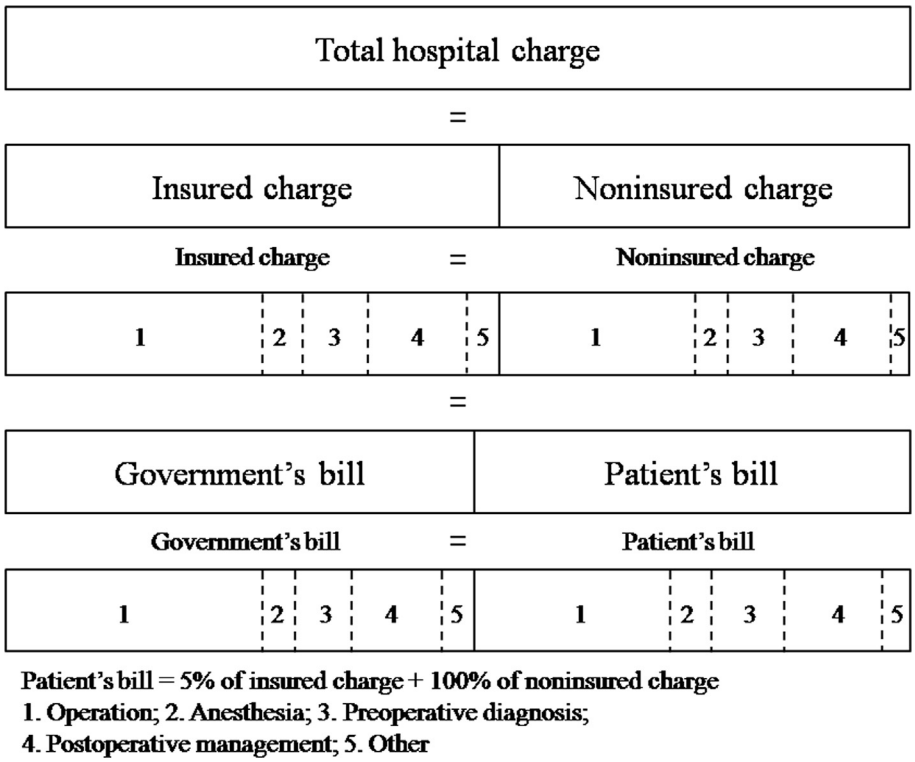

Figure 1 Health care costs for surgical patients in Korea.

(sigmoid colectomies) gradually increased from $958.62 and $1067.19 in January 2009 to $1125.60 and $1171.01 in December 2014, respectively. The costs of instruments differed according to the number and type of laparoscopic access devices used, and those were thus different between SILS and CLS. The cost of a trocar for CLS was approximately $115.60, for which patients would pay only 5% ($5.78) because the NHIC had approved trocars as an IC. By contrast, the access for SILS (an Octo™ port) cost $408.90, which was an NIC, to be paid by the patient, up until December 2014. In 2015, this access device became approved as an IC, so it was thereafter partly reimbursed by the NHIC. Anesthesia fees were fixed for the first hour, and increased in a manner proportional to the operation time.

Fees for preoperative diagnoses were composed of the costs for laboratory studies, colonoscopies, and imaging studies. A colonoscopy before surgery was not performed if the patient had received a colonoscopy at a private clinic and its quality was satisfactory. However, endoscopic tattooing via a colonoscopy was performed when the tumor seemed to be a T1 or T2 lesion and could not be found laparoscopically. Imaging studies included abdominal computed tomography (CT) and chest CT. Positron emission tomography was not routinely performed except in cases where metastatic colon cancer was suspected.

Fees for postoperative management included costs of the hospital room, diet, medications, laboratory and imaging studies, transfusions, and consultations. These fees included the costs associated with management of the early postoperative complications that occurred during hospitalization. "Other" costs included fees for consultations by other departments, the issuing of medical documents, rehabilitation, and other costs associated with postoperative management. Costs that can be incurred in the Korean health care system have been described in detail in previous studies, although those studies focused on costs associated with rectal cancer.[16,17] One USD was calculated to be 1,125 won, according to the exchange rate from August 2017.

2.3. Statistical analysis

Because costs could be biased if the baseline patient characteristics in the two groups were not balanced, propensity score-matching with a ratio of 1:1 according to the following nine variables was performed: sex, age, BMI, alcohol intake, smoking, ASA physical status class, previous abdominal surgery, combined resection, and pathological stage. Continuous variables were compared using Student's *t*-tests, and categorical variables were compared using the χ^2 tests or Fisher's exact tests. *P*-values <0.05 were considered statistically significant. Incremental cost-effectiveness ratio (ICER) was calculated for significantly different variables between two groups. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, version 20.0, Chicago, IL, USA).

3. Results

From July 2009 and September 2014, 152 patients underwent SILS and 509 patients underwent CLS at our

Table 1 Baseline patient characteristics.

Variable	Overall cohort			After matching		
	SILS (n = 152)	CLS (n = 509)	P	SILS (n = 144)	CLS (n = 144)	P
Male sex	79 (52)	292 (57.4)	0.264	78 (54.2)	79 (54.9)	>0.999
Age (years)*	62.7 (11.2)	61.8 (11.6)	0.405	62.8 (10.9)	62.4 (10.9)	0.754
BMI (kg/m^2)*	23.4 (3.0)	23.1 (2.9)	0.297	23.2 (2.9)	23.4 (2.8)	0.505
Alcohol intake	64 (42.1)	254 (49.9)	0.097	62 (43.1)	61 (42.4)	>0.999
Smoking	49 (32.2)	158 (31)	0.842	46 (31.9)	44 (30.6)	0.899
ASA class			0.795			0.675
I	51 (33.6)	158 (31)		48 (33.3)	51 (35.4)	
II	73 (48)	266 (52.3)		69 (47.9)	69 (47.9)	
III	27 (17.8)	81 (15.9)		27 (18.8)	24 (16.7)	
IV	1 (0.7)	4 (0.8)		0 (0)	0 (0)	
Previous abdominal surgery	31 (20.4)	100 (19.6)	0.908	31 (21.5)	29 (20.1)	0.885
Tumor location						
Cecum	6 (3.9)	17 (3.3)	<0.001	6 (4.2)	1 (0.7)	0.281
Ascending colon	28 (18.4)	159 (31.3)		26 (18.1)	29 (20.1)	
Transverse colon	6 (3.9)	36 (7.1)		6 (4.2)	8 (5.6)	
Descending colon	1 (0.7)	8 (1.6)		0 (0)	0 (0)	
Sigmoid colon	111 (73)	289 (56.8)		106 (73.6)	106 (73.6)	

Values in parentheses are percentages unless otherwise indicated; *values are means (S.D.s); ASA, American Society of Anesthesiologists; BMI, body mass index; CLS, conventional laparoscopic surgery; SILS, single-incision laparoscopic surgery.

institution. After propensity score-matching, there was no difference in baseline characteristics between the SILS and CLS groups (n = 144 in each group, Table 1). The left colon was a more common location for tumors than the right colon in both groups (73.6% left vs. 26.4% right in both groups). Perioperative outcomes, including operation time and length of hospital stay, were similar in both groups (Table 2). The total skin incision length was shorter in the SILS group than in the CLS group (3.6 cm vs. 7.5 cm, $P < 0.001$). Both early and late postoperative morbidity rates were similar between the two groups. There were four readmissions due to late complications in each group (2.8% vs. 2.8%, $P > 0.999$).

The total hospital charges did not differ between the two groups (Table 3). However, the NICs were higher in the SILS group than in the CLS group ($3936.70 vs. $3489.87, $P < 0.001$), whereas the ICs were not different between groups. Consequently, the patients' total hospital bill (5% of the ICs + 100% of the NICs) was also higher in the SILS group than in the CLS group ($4184.82 vs. $3735.00, $P < 0.001$), whereas the government's bill was similar in both groups. Specifically, the fees for anesthesia, preoperative diagnosis, postoperative management, and other costs were not different between the two groups. The only difference was in the cost of instruments and supplies component of the operation fee ($3157.87 vs. $2810.67, $P < 0.001$). This difference ($347.20) was an important factor contributing to the difference in total hospital charges between the two groups ($417.60), although this difference was not significantly different. ICER for total incision length, which was only different between the two groups, in 'total hospital charge' and patient's bill and government's bill in 'cost of instruments and supplies' were -$107.08/1 cm, -$109.70/1 cm, and $80.64/1 cm, respectively.

Table 2 Perioperative outcomes.

Variable	SILS (n = 144)	CLS (n = 144)	P
Operation time (minutes)*	173.5 (59.0)	181.7 (63.3)	0.454
Combined resection	13 (9)	11 (7.6)	0.832
Total length of incisions (cm)*	3.6 (0.8)	7.5 (0.9)	<0.001
Length of hospital stay (days)*	6.4 (3.1)	7.0 (2.7)	0.084
Early postoperative complications[a]	18 (12.5)	22 (15.3)	0.736
Anastomotic leakage	1 (0.7)	0 (0)	
Ileus	4 (2.8)	5 (3.5)	
Intraabdominal fluid collection	5 (3.5)	3 (2.1)	
Wound infection	8 (5.6)	8 (5.6)	
Others	0 (0%)	6 (4.2%)	
Late postoperative complications[b]	8 (5.6)	6 (4.2)	0.785
Anastomotic stenosis	1 (0.7)	0 (0)	
Ileus	1 (0.7)	0 (0)	
Incisional hernia	3 (2.1)	4 (2.8)	
Small bowel obstruction	3 (2.1)	2 (1.4)	
Readmission	4 (2.8%)	4 (2.8%)	>0.999

Values in parentheses are percentages unless otherwise indicated; *values are means (S.D.s); CLS, conventional laparoscopic surgery; SILS, single-incision laparoscopic surgery.
Combined resection refers to cholecystectomies, hepatectomies, and hysterectomies.
[a] Within 30 days of surgery.
[b] From 30 days after surgery to February 2018 (the final follow-up date).

Table 3 Perioperative costs in United States dollars (1 USD = 1,125 won).

Variable	SILS (n = 144)	CLS (n = 144)	P
Total hospital charges	8770.40 (2440.12)	8352.80 (1964.20)	0.099
Insured charge	4833.77 (1582.35)	4862.91 (1475.52)	0.872
Noninsured charge	3936.70 (1003.38)	3489.87 (936.16)	<0.001
Patient's bill	4184.82 (1158.15)	3735.00 (1002.19)	<0.001
Government's bill	4585.65 (1538.51)	4617.80 (1397.46)	0.853
Operation	5325.57 (942.27)	4945.40 (708.58)	<0.001
Surgery and treatment fee	2167.70 (449.09)	2134.73 (343.25)	0.486
Cost of instruments and supplies	3157.87 (623.89)	2810.67 (478.51)	<0.001
Anesthesia	571.03 (168.45)	579.64 (124.16)	0.623
Preoperative diagnosis	936.95 (635.18)	899.10 (618.17)	0.610
Postoperative management	1858.69 (1058.64)	1892.22 (1137.17)	0.797
Other	81.46 (525.59)	36.43 (47.55)	0.308

Values are means (S.D.s); CLS, conventional laparoscopic surgery; SILS, single-incision laparoscopic surgery.

The additional costs incurred in eight patients due to hospital readmission caused by late complications are listed in the Table 4. Among them, seven patients received surgery under general anesthesia (i.e. Clavien-Dindo grade IIIb) and one received surgery under local anesthesia (i.e. Clavien-Dindo grade IIIa). There was no difference in these additional costs between the patients in the SILS group and those in the CLS group.

4. Discussion

The advantages of MIS, including fast recovery, shorter total incision length, and less pain compared to open surgery, are attractive to patients as well as surgeons. However, although favorable outcomes associated with SILS have been observed, SILS has not become a widespread option for colon cancer due to certain questions that remain unanswered with solid evidence. For instance, it is not yet clear whether the shorter total incision length with SILS directly produces superior cosmetic results,[11,15] which may be resolved in the future using objective methods, such as questionnaires about cosmetic results. It is likewise unclear whether SILS is indicated for all patients because of the technical difficulty of the procedure.[12–14,18] Furthermore, the learning curve for SILS has not firmly been established, and it is unclear whether novices, as well as MIS-experienced surgeons, can successfully perform the procedure. In addition, little research exists comparing the costs of SILS with those of CLS for colon cancer.[19] Among these issues, we have previously reported the learning curves associated with SILS for right colectomies and anterior resections for colon cancer.[12–14] Here, we attempted to objectively answer one of the remaining issues: the costs of these procedures. We found that the costs of SILS and CLS for colon cancer were similar for patients who underwent treatment during both short- and long-term time periods.

Total hospital charges were not significantly different between the SILS and CLS groups (Table 3). Fees for the preoperative diagnosis were similar because the diagnostic studies for colon cancer are the same for all patients at our institution, regardless of the surgical method used (SILS, CLS, robotic surgery, or open surgery). Anesthesia fees, which were proportional to the operation time, were similar because of the similar operation times associated with SILS and CLS. Fees for postoperative management can increase if the hospital stay is lengthened because of complications, late resumption of a normal diet, or for other reasons. However, these fees were also similar between the two groups, because the average postoperative course did not differ between the groups.

Although it was not statistically significant, a small difference was noted in the total hospital charges between

Table 4 Additional costs associated with readmission due to late complications.

	SILS (n = 144)	CLS (n = 144)	P
Length of hospital stay (days)	8.50 (1.29)	8.00 (2.44)	0.734
Total hospital charges	2383.08 (311.89)	2288.33 (269.23)	0.662
Insured charge	1369.18 (101.47)	1317.05 (85.23)	0.462
Noninsured charge	971.28 (195.49)	1013.90 (217.23)	0.780
Patient's bill	1082.35 (221.79)	1037.13 (198.99)	0.772
Government's bill	1300.73 (96.42)	1251.20 (80.94)	0.462
Operation	1269.90 (165.70)	1302.80 (121.89)	0.760
Anesthesia	122.70 (16.14)	133.15 (17.45)	0.413
Preoperative diagnosis	348.80 (96.73)	306.55 (38.41)	0.463
Postoperative management	641.68 (228.08)	545.83 (245.68)	0.588

Values are means (S.D.s); CLS, conventional laparoscopic surgery; SILS, single-incision laparoscopic surgery.

the SILS and CLS groups. This difference was due to a combination of the difference in cost of the access device for SILS compared with that used for CLS, and the unique features of the Korean health care system. According to the policies of the NHIC, which approves certain instruments or techniques as ICs only after sufficient evidence has been provided, the cost of the access device for SILS was classified as NIC until December 2014. By contrast, the costs of trocars, used in CLS, were already approved as ICs in 2005. Therefore, in the current study patients in the SILS group paid 100% of the costs of the access device. In contrast, patients in the CLS group paid only 5% of the costs of the four or five trocars ($23.12 or $28.90, respectively). After several reports verified the safety of SILS for colorectal diseases, the NHIC approved the cost of the SILS access device as an IC starting in 2015. Thereafter, the patients' portion of the cost for the SILS device was reduced to $20.44 (5% of $408.90). Thus, the costs of SILS and CLS would be similar in studies conducted in 2015 and later. This means that, as of 2015 in Korea, patients who want to undergo SILS no longer have to pay $450 more to attain a shorter total incision length than that associated with CLS.

In terms of rectal cancer, the overall costs have been reported to be different than those associated with colon cancer surgery.[16,17] The surgery fee for rectal cancer was higher than that of colon cancer in Korea, possibly due to the difficulty of the procedure. The operation time for rectal surgery was usually longer than that of colon surgery, which consequently increases the fees associated with the operation, anesthesia, and postoperative management.

A few previous reports have evaluated the costs of SILS for various diseases. Beck and colleagues showed similar clinical outcomes between SILS and CLS for cholecystectomies, with a small, non-significant difference in cost ($746) between the two groups.[20] In contrast, Leung et al. showed that single-incision laparoscopic cholecystectomy was associated with higher total hospital charges compared with CLS in their prospective randomized trial.[21] A small study from the United Kingdom, in contrast, showed SILS to be cost-effective for common pediatric surgeries, such as appendectomies, nephrectomies, and oophorectomies.[22] Moreover, there have been several studies comparing SILS and single-incision robotic surgery.[23]

In contrast, few reports have assessed the costs of SILS for colorectal diseases. Sulu et al. showed that the total costs were not different between the SILS and CLS groups, although SILS was associated with shorter operation time and consequently lower anesthesia fee.[24] However, malignancies accounted for only 20% of their cohort. Unlike for benign diseases, surgery for malignant diseases requires extensive lymph node harvesting and sufficient resection of the mesocolon to achieve better oncological outcomes. In terms of treating malignancies, Fujii et al. suggested that SILS was advantageous because of the lower cost of access instruments ($580 SILS vs. $713 CLS).[25] Although their analysis identified the cost of trocars as the cause of this difference, these authors did not present data on the total hospital charges, so the overall causes of the cost differences remain unclear. Van der Linden and colleagues performed a cost analysis of SILS and CLS and analyzed each category of costs.[19] They showed that the total costs tended to be higher with SILS than with CLS for patients in their early period (although this difference was not statistically significant), and that the costs became comparable in their late period, as the experience of SILS accumulated and the clinical outcomes associated with SILS improved. Some clinicians have tried to reduce costs by building a glove port instead of purchasing SILS access devices.[26,27]

In the current study, we found no difference in the costs raised by late complications between patients who underwent SILS and those who underwent CLS (Table 4). The similar perioperative outcomes of SILS and CLS seemed to yield similar costs. Given that SILS was superior to CLS with regards to total incision length and potential cosmetic benefit, and given the lack of difference in costs of the two surgical methods, surgeons and patients can consider SILS as a viable option for treating colon cancer, although adequate indications were premises.

To our knowledge, this is the first study to make a detailed comparison of the differences in costs of SILS and CLS for treating colon cancer based on long-term follow-up care. Our results not only consolidate evidence regarding the safety of SILS, but also provide information regarding the cost analysis of SILS, for treating this malignancy. However, our study has limitations that should be noted. First, although the possibility of allocation bias was reduced by propensity score-matching, selection bias may be still inevitable in this retrospective study. Second, the number of patients included from a single institution was relatively small. Third, relatively low BMI of the Asian patients, although the selection of patients was not performed, was an obstacle for general application of SILS, especially in Western countries. Fourth, the study period encompassed several years before 2015, so the cost analysis does not fully reflect the current situation in Korea, as the SILS access device is now approved as an IC by the NHIC. Future studies are required to address this issue. Fifth, this is not a cost-effectiveness study, which requires a certain statistical methods using some useful tools such as quality of life questionnaires. However, the prospective data could not be gained due to the retrospective nature. Last, the application of our cost analysis, as well as clinical outcomes, to areas outside Korea may be inappropriate, because each country has its own unique health care system and there could be differences in patient populations from Korea and other parts of the world.

In conclusion, SILS appears to be safe in terms of perioperative and long-term outcomes compared with CLS. Moreover, the costs of SILS for colon cancer were generally similar to those of CLS. Therefore, SILS can be considered a reasonable treatment option for colon cancer for selective patients.

Conflict of interest

The authors have no conflict of interests to disclose.

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