



# Resident Involvement in Microsurgery: An American College of Surgeons National Surgical Quality Improvement Program Analysis

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**OBJECTIVE:** In the current healthcare climate, there is increased focus on medical errors, patient outcomes, and the influence of resident participation on these metrics. Other studies have examined the influence of resident involvement on surgical outcomes, but the arena of microsurgery, with added complexity and learning curve, has yet to be investigated.

**DESIGN:** A retrospective analysis of the American College of Surgeons National Surgical Quality Improvement Program database was performed to find patients undergoing procedures with free tissue transfer by screening for Current Procedural Terminology codes. Primary outcomes measured include flap failure, wound, infectious, and major and minor complications.

**SETTING:** This study was conducted at the Methodist Hospital, an academic hospital located in Houston, Texas.

**PARTICIPANTS:** Patients in the National Surgical Quality Improvement Program database between the years 2005 and 2012 undergoing microsurgical procedures were included in this analysis.

**RESULTS:** A total of 1466 patients met inclusion criteria. There was a statistically significant association of major complications with age, peripheral vascular disease, American Society of Anesthesiologists (ASA) classification of 3 or greater, total operative time, and year of operation. Multivariate analysis on minor complications demonstrated significant association with ASA class of 3 or 4.

Resident involvement was not a significant factor among any outcome measures including major complications, minor complications, flap failure, wound complications, infectious complications, bleeding requiring transfusion, and unexpected reoperation rates within 30 days.

**CONCLUSIONS:** This study provides further evidence in support of the claim that resident involvement in microsurgery is safe and effective, with similar rates of major complications, minor complications, flap failure, and unexpected reoperation. High ASA classification and history of peripheral vascular disease were strong predictors of major complications and should be optimized preoperatively before free tissue transfer. Later years were associated with decreased major complication rates, which may be reflective of enhanced supervision standards. (J Surg Ed 74:1124-1132. © 2017 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

**KEY WORDS:** microsurgery, clinical aspect of plastic microsurgery, clinical outcomes research, resident training

**COMPETENCIES:** Practice-Based Learning and Improvement

## INTRODUCTION

The field of modern microvascular surgery has evolved into a valuable tool for surgeons in multiple specialties including plastic and reconstructive surgery, orthopedic surgery, neurosurgery, cardiovascular surgery, general surgery, and urology.<sup>1,2</sup> Microsurgery is an indispensable technique for complex reconstructions, and is therefore an essential component in training plastic and reconstructive surgeons.<sup>3,4</sup>

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With advances to the field, residents are exposed to microsurgery earlier in their training.<sup>5</sup> Complex microsurgical cases necessitate a skilled surgical assistant or second surgeon. In the academic setting where many of such procedures take place, a resident or fellow is therefore frequently involved. With increased focus on medical errors, adverse events, and patient outcomes,<sup>6</sup> the influence of resident participation on these metrics is an area currently being investigated. The involvement of trainees in patient care has raised concerns about their experience and abilities, leading some patients to request that house staff not participate in their care.<sup>7</sup>

Specifically to microsurgery, there is a steep learning curve and demand for highly refined manual dexterity, hand-eye coordination, and good judgement in a clinical setting which requires considerable time in practice.<sup>8,9</sup> It has been demonstrated that the surgeon variable is a major determinant of success or failure in microsurgery, with studies demonstrating a significant learning curve before achieving high success rate.<sup>10</sup>

Prior research exploring resident involvement correlated to patient outcomes among different subspecialties and procedure types has produced mixed results. Although some of these studies resulted in poorer outcomes with resident involvement,<sup>11-19</sup> others reported no significant detriment in outcomes with resident involvement.<sup>5,20-24</sup> The effect of resident involvement in plastic surgery on a large scale has been studied demonstrating safety;<sup>20</sup> however, the arena of microsurgery, with added complexity and learning curve, has limited data in the literature. Given this learning curve and operator dependence unique to the field of microsurgery, outcomes in cases with resident involvement should be examined.<sup>25</sup> The purpose of this study was to examine

the influence of resident involvement in microsurgical outcomes.

## MATERIALS AND METHODS

### Data Source

Participant Use Data Files for 2005 to 2014 were downloaded from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) website (<http://www.acsnsqip.org/>). This database is comprised of data regarding preoperative comorbidities, intraoperative variables, and 30-day postoperative mortality and morbidity outcomes in surgeries performed at participating institutions. The details for data collection methods are available through the program.<sup>26</sup> Data for years 2013 and 2014 were excluded given changes in data collection of key variables including flap failure<sup>27,28</sup> and discontinuation of variables which allowed for determination of resident involvement in cases. This study was conducted in accordance with the principles outlined in the Declaration of Helsinki.

### Patient Selection

We performed a retrospective analysis of the database to obtain data on all patients undergoing procedures with microvascular anastomoses between 2005 and 2012. The following American Medical Association Current Procedural Terminology codes were screened as both primary and secondary operations to identify patients undergoing microsurgical procedures: 15756 to 15758, 15842, 19364, 20955 to 20957, 20962, 20969 to 20973, 26551, 26553, 26554, 26556, 43496, and 49906 (Table 1).

**TABLE 1.** CPT Codes

CPT Code	Procedure
15756	Free muscle flap with or without skin graft with microvascular anastomosis
15757	Free skin flap with microvascular anastomosis
15758	Free fascial flap with microvascular anastomosis
15842	Flap for face nerve palsy
19364	Breast reconstruction
20955	Bone graft with microvascular anastomosis
20956	Bone graft with microvascular anastomosis; iliac crest
20957	Bone graft with microvascular anastomosis; metatarsal
20962	Bone graft other than fibula, iliac crest, or metatarsal
20969	Free osteocutaneous flap with microvascular anastomosis, other than iliac crest, rib, metatarsal, or great toe
20970	Free osteocutaneous flap with microvascular anastomosis; iliac crest
20971	Free osteocutaneous flap with microvascular anastomosis
20972	Free osteocutaneous flap with microvascular anastomosis; metatarsal
20973	Free osteocutaneous flap with microvascular anastomosis; great toe
26551	Toe-to-hand transfer with microvascular anastomosis; great toe "wrap-around" with bone graft
26553	Other than great toe, single
26554	Other than great toe, double
26556	Free toe joint transfer with microvascular anastomosis
43496	Free jejunum transfer with microvascular anastomosis
49906	Free omental flap with microvascular anastomosis

CPT, Current Procedural Terminology.

## Statistical Analysis

Resident participation was determined by the ATTEND variable in the database, indicating whether an attending was present with or without a resident during the procedure. Descriptive statistics, as well as complication profiles, were calculated for the study population. Primary outcomes measured include flap failure, wound, infectious, and major and minor complications. We defined wound complications as one or more of the following: superficial site infection, deep infection, or wound dehiscence. Infectious complications were composed of organ-space infections, pneumonia, urinary tract infection, sepsis, or septic shock, or all of these. Outcomes further included respiratory, thromboembolic, renal, cardiac, neurologic, and bleeding complications. Minor complications included incisional infections and urinary tract infections. Major complications encompassed organ-space infections, cardiac events, neurologic events, ventilator dependence, pneumonia, venous thromboembolic events, unplanned return to the operating room, renal failure, and sepsis/septic shock. Demographic data included age, body mass index (BMI), and sex. Lifestyle variables

included smoking status within the year before admission and consumption of alcohol greater than 2 drinks per day in the 2 weeks leading up to admission. Clinical factors followed include steroid use radiotherapy <90 days before surgery, and chemotherapy <30 days before surgery. Comorbidities that were followed include diabetes, hypertension, severe chronic obstructive pulmonary disease (COPD), bleeding disorders, peripheral vascular disease (PVD), and transient ischemic attack or stroke with/without neurological impairment (cerebrovascular disease).

Chi-square and *t* tests were used to perform univariate analysis on categorical and continuous variables, respectively. Significance was defined with a *p* < 0.05, and variables with a *p* < 0.1 were included in a multivariate logistical regression analysis to control for confounders. Additional factors were included in the multivariate analysis based on clinical pertinence. Factors were excluded from multivariate regression analysis if the number of cases per instance was less than 10. Multivariate analysis was performed to determine the effect of comorbidities on complication rate. All analyses were performed using SPSS version 24.0 (IBM Corp., Armonk, NY). This study was

**TABLE 2.** Analysis of Patient Demographics and Perioperative Variables

Characteristic	Baseline Characteristics		p Value
	Attending Only	Resident Involved	
Number of patients (total N = 1471)			
Age (y) mean ± SD	53.4 ± 13.9	55.2 ± 14.5	0.017
BMI (kg/m <sup>2</sup> ) mean ± SD	28.2 ± 7.01	27.8 ± 6.3	0.038
Sex			
Male	189 (36.6)	380 (39.8)	0.350
Female	328 (63.4)	573 (60.1)	0.350
Clinical factors			
Smoker	99 (19.1)	171 (17.9)	0.562
EtOH	19 (3.7)	50 (5.2)	0.206
Steroid use	8 (1.5)	29 (3.0)	0.081
Radiotherapy	13 (2.5%)	18 (1.9)	0.365
Chemotherapy	21 (4.1)	45 (4.7)	0.432
Comorbidities			
Hypertension	186 (36.0)	363 (38.1)	0.432
Peripheral vascular disease	11 (2.1)	9 (0.9)	0.086
COPD	11 (2.1)	40 (4.2)	0.039
Diabetes	52 (10.1)	96 (10.1)	0.998
Congestive heart failure	1 (0.2)	3 (0.3)	0.670
Dialysis	3 (0.6)	4 (0.4)	0.668
Bleeding disorder	16 (3.1)	25 (2.6)	0.598
CVA	17 (3.3%)	21 (2.2%)	0.227
Operative factors			
Operative time (min) ± SD	418 ± 229	519 ± 200	<0.001
ASA			<0.001
1	27 (5.2)	40 (4.2)	
2	270 (52.2)	397 (41.6)	
3	195 (37.7)	462 (48.4)	
4	24 (4.6)	55 (5.8)	
ASA 3 or 4*	219 (42.5)	517 (54.2)	<0.001
Total hospital length of stay	8.4 d	8.5 d	0.833

CVA, cerebrovascular accident; EtOH, ethanol; SD, standard deviation.

\*In comparison to ASA 1 and 2.

approved by our institutional review board and the authors adhered to the Declaration of Helsinki at all times.

## RESULTS

A total of 5966 patients were initially identified as undergoing microvascular procedures. After removing data for years 2013 and 2014 for missing key variables<sup>29</sup> and removing incomplete entries, 1466 patients remained. Attendings alone conducted 514 (35.1%) cases and residents participated in 952 (64.9%) cases. Patient baseline preoperative data are presented in Table 2. No statistical significance was observed between groups about sex and clinical factors including smoking status, alcohol consumption, steroid use, radiotherapy, or chemotherapy. Comorbidities generally did not show significance between the groups, including hypertension, PVD, diabetes, congestive heart failure, dialysis, bleeding disorders, and cerebrovascular accidents. Some factors did suggest statistical significance, however, including age, BMI, and history of COPD. Resident-involved cases had a higher mean age (55.2 vs 53.4 years old,  $p = 0.017$ ) and lower average BMI (27.8 vs 28.2,  $p = 0.038$ ). Cases had similar comorbidity profiles; however, cases with residents consisted of statistically significant more patients with COPD (4.2 vs 2.1 %,  $p = 0.039$ ) and American Society of Anesthesiologists (ASA) class 3 or 4 (54.2 % vs 42.5 %,  $p < 0.001$ ).

Table 3 demonstrates a univariate analysis demonstrating the frequency of 30-day postoperative complications without controlling for confounding variables. Major complication rate was 20.3% without residents and 19.3% with resident involvement and demonstrated no statistical significance. There were significantly more wound complications, instances of bleeding requiring transfusion, and minor

complications (particularly superficial infections) in resident-involved cases than attending-only cases. There was no statistical significance in flap failure, infection, respiratory, thromboembolic, renal, cardiac, or neurologic complications. No statistical difference was noted in unexpected return to the operating room within 30 days between the 2 groups.

Univariate analysis was used to determine the relationship between preoperative characteristics and major complications (Table 4). Factors that achieved significance include alcohol consumption, PVD, ASA classification of 3 or 4, and hypertension.

Multivariate analysis determined the relationship between preoperative characteristics and comorbidities with major complications (Table 5) after controlling for confounding variables. Variables included in the multivariate analysis included those that achieved a  $p < 0.1$  in univariate analysis or had clinical relevance. Factors achieving statistical significance included age, PVD, ASA class 3 or 4, total operative time, and year of operation. Increasing year of operation was associated with lower rates of major complications, specifically the years 2011 and 2012. Resident involvement, sex, alcohol consumption, and hypertension were not associated with statistically significant increased major complication rates. Multivariate analysis on minor complications (Table 6) demonstrated significant association with ASA classification of 3 or 4 only. The year of operation did not reach statistical significance for association with minor complications.

Multivariate analysis was also performed for other outcomes (Table 7) to determine if resident involvement achieved significance after controlling for confounding variables. Resident involvement was not a significant factor among any of the outcomes including flap failure, wound complications, infectious complications, bleeding requiring transfusion, and rates of unexpected reoperation within 30 days.

**TABLE 3.** Univariate Analysis of Postoperative Complications

Complication	Attending Only, n (%)	Resident Involved, n (%)	Unadjusted OR (95% CI) (Res vs Att)	p Value
Flap failure*	23 (6.2)	18 (6.4)	0.78 (0.48-1.24)	0.290
Wound	32 (6.2)	96 (10.1)	1.70 (1.11-2.57)	0.012
Infection	33 (6.4)	54 (5.7)	0.88 (0.56-1.38)	0.575
Respiratory	24 (4.6)	36 (3.8)	0.81 (0.48-1.37)	0.421
Thromboembolic	11 (2.1)	15 (1.6)	0.74 (0.34-1.61)	0.440
Renal	0 (0)	3 (0.3)		0.202
Cardiac	2 (0.4)	11 (1.2)	3.00 (0.66-13.6)	0.134
Neurologic	3 (0.6)	2 (0.2)	0.36 (0.06-2.16)	0.244
Bleeding requiring transfusion	57 (11.0)	270 (28.3)	3.19 (2.34-4.34)	<0.001
Major complications	105 (20.3)	184 (19.3)	0.94 (0.72-1.23)	0.638
Minor complications	19 (3.7)	72 (7.5)	2.14 (1.28-3.59)	0.003
Unexpected return OR	69 (19.2)	51 (17.6)	0.90 (0.61-1.35)	0.620

OR, odds ratio.

\*Flap failure rate was calculated using 2005 through 2010 data, therefore a total of 360 patients in the attending-only group were identified and 289 in the resident-involvement group. Years 2011 and 2012 were excluded because of incomplete data reporting.<sup>27</sup>

**TABLE 4.** Univariate Analysis for Factors Associated With Major Complications

Factor	Unadjusted OR (95% CI)	p Value
Male sex	1.24 (0.96-1.61)	0.106
Diabetes	1.04 (0.68-1.60)	0.840
Smoker	1.25 (0.91-1.72)	0.178
EtOH	1.72 (1.01-2.94)	0.046
COPD	1.58 (0.84-2.96)	0.153
Peripheral vascular disease	4.20 (1.73-10.19)	0.001
ASA 3 or 4*	1.89 (1.45-2.47)	<0.001
Steroid	0.95 (0.41-2.19)	0.910
Radiotherapy	1.44 (0.64-3.24)	0.635
Chemotherapy	1.21 (0.67-2.19)	0.519
Hypertension	1.52 (1.17-1.97)	0.002
Bleeding disorder	0.70 (0.29-1.67)	0.413
CVA	1.53 (0.73-3.19)	0.257

CVA, cerebrovascular accident; EtOH, ethanol; OR, odds ratio.

\*In comparison to ASA 1 and 2.

## DISCUSSION

Over the past several years, there has been increasing interest in developing surgical education strategies<sup>29</sup> including microsurgical competency,<sup>3,9,25,30</sup> and it is of critical importance to maintain the established levels of standardization and expertise for microsurgeons in training.<sup>5</sup> The data here can be used to enhance the understanding of resident effect on outcomes thus providing an opportunity to more safely and effectively incorporate resident education in patient care. Hirche et al.<sup>5</sup> through retrospective analysis of 391 free-flap procedures under the supervision of an experienced microsurgeon vs a resident in training, demonstrated that microsurgery can be safely applied in resident training. Patel and Lin<sup>31</sup> studied 93 head and neck free flaps with resident involvement retrospectively and demonstrated an overall success rate of 97%. These results are in accordance with data from our study in that high levels of free-flap success were achieved and cases with resident involvement proved to have similar complication rates.

The principal aim of this study was to elucidate the influence of resident involvement on microsurgical procedures. Our results demonstrate that resident involvement in

microsurgical cases shows similar rates of major complication, minor complication, and flap failure rates compared with cases without resident involvement. It is important to note that in cases with resident involvement, patients were on average sicker with higher rates of severe COPD, older age, and greater proportion under ASA classification 3 or 4. The preoperative condition of these patients may also account for the increased rates of wound complications and bleeding requiring transfusion in the resident-involved cohort. After controlling for these variables, there was no difference in the targeted outcomes. Our data, with an overall flap failure rate of 6.3% between both groups, are consistent with the literature in microsurgical procedure failure rates.<sup>32-35</sup> Additionally, infectious, respiratory, thromboembolic, renal, cardiac, and neurologic complications did not differ significantly either.

Similar to other studies,<sup>36-38</sup> ASA was found to be a strong determinant of postoperative complications after microsurgical procedures. PVD as a relative contraindication to free-flap surgery has also been controversial<sup>36,39,40</sup>; however, our data suggest a significant correlation with major complications. More specifically, PVD was associated with increased occurrence of reoperation, flap failure, and

**TABLE 5.** Multivariate Analysis for Factors Associated With Major Complications

Factor	Adjusted OR (95% CI)	p Value
Resident involvement	1.00 (0.71-1.42)	0.989
Age	1.01 (1.00-1.02)	0.034
Male sex	0.98 (0.73-1.31)	0.884
BMI	1.01 (0.99-1.03)	0.585
Peripheral vascular disease	3.43 (1.36-8.61)	0.009
EtOH	1.46 (0.82-2.61)	0.394
Hypertension	0.88 (0.65-1.19)	0.394
Operative time	1.001 (1.001-1.002)	<0.001
ASA 3 or 4*	1.55 (1.15-2.09)	0.004
Year of operation	0.84 (0.75-0.94)	0.003

EtOH, ethanol; OR, odds ratio.

\*In comparison to ASA 1 and 2.

**TABLE 6.** Multivariate Analysis for Factors Associated With Minor Complications

Factor	Adjusted OR (95% CI)	p Value
Resident involvement	1.78 (0.96-3.29)	0.067
Age	1.01 (0.99-1.03)	0.334
Male sex	0.98 (0.62-1.56)	0.944
BMI	1.00 (0.97-1.03)	0.900
Peripheral vascular disease	2.61 (0.72-9.53)	0.145
EtOH	0.55 (0.16-1.84)	0.330
Operative time	1.001 (1.000-1.002)	0.307
ASA 3 or 4*	1.93 (1.18-3.16)	0.009
Year of operation	1.05 (0.86-1.30)	0.623

EtOH, ethanol; OR, odds ratio.

\*In comparison to ASA 1 and 2.

septic shock. Neither ASA classification nor PVD should be considered as absolute contraindications to microsurgical treatments; however, patients with these conditions are more prone to postoperative complications; therefore, surgeons and anesthesiologists should be vigilant of these comorbidities. With adequate precautions, complication rates in these patient groups can be minimized. Although diabetes and smoking are associated with PVD, these factors did not demonstrate a significant association with complications. The effect of operative time on free-flap outcomes is not clear. Serletti et al. found that operating time is a predictive parameter for postoperative complications during free tissue transfer; however, other studies have demonstrated no significant effect.<sup>37</sup> Our data demonstrate a small but significant correlation between operating time and overall complications. In our study, cases with resident involvement were highly correlated with longer operative times, on average 90 minutes longer. However, this lengthened operating time may be influenced by sicker patients in the resident-involved group as demonstrated in Table 3. Jordan et al.<sup>20</sup> demonstrated, through analysis of the NSQIP database, that a clear selection bias was present favoring resident participation in more complex cases. Additionally, the teaching and training of residents contributes to the overall length of the case. However, owing to the limitation of the NSQIP data set, no specific conclusion can or should be drawn from the increased operative times.

The data presented here provide valuable information for surgeons in both preoperative decision making and

counseling patients about the risks of undergoing procedures involving free tissue transfers. Consistent with the literature on advancing age in microsurgical outcomes,<sup>40</sup> there was a minimal effect of age on major complications. As such, other active comorbidities such as smoking, obesity, and ASA status should be optimized.<sup>40</sup> The deleterious effects of diabetes, smoking, and bleeding disorders, which are currently controversial,<sup>40</sup> did not demonstrate statistical significance in our study. Our data suggest an increased major complication rate associated with PVD, which is not unexpected given the critical importance of sufficient arterial and venous vascularity.

Regarding plastic surgery, Jordan et al.<sup>20</sup> examined 2006 through 2010 NSQIP data for all reconstructive plastic surgery cases and found that resident involvement resulted in similar complication profiles. Our study differs in that we focused on microsurgery, which is unique in its learning curve and operator dependence.

The year of operation demonstrated significance, with earlier years associated with greater rates of major complications. This may be explained by the recent focus on increased resident supervision along with other changes to graduate medical education.<sup>41,42</sup> The Accreditation Council for Graduate Medical Education (ACGME) revised the Common Program Requirements in 2011 to include enhanced supervision standards that explicitly defined the levels of supervision for residents at each level of their training.<sup>41</sup> In an effort to increase patient safety and optimize resident education there has been a trend toward

**TABLE 7.** Multivariate Analysis of Resident Involvement Across Outcomes. Multivariate Analysis was Controlled for Age, Sex, ASA Classification, Peripheral Vascular Disease, Operative Time, Steroids, EtOH, and BMI

Outcome	Adjusted OR (95 % CI)	p Value
Flap failure*	1.38 (0.70-2.73)	0.350
Wound complications	1.51 (0.98-2.32)	0.064
Infectious complications	0.69 (0.43-1.10)	0.116
Bleeding requiring transfusion	1.30 (0.47-3.59)	0.610
Unexpected return to OR	0.82 (0.60-1.12)	0.221

EtOH, ethanol; OR, odds ratio.

\*Flap failure rate was calculated using 2005 through 2010 data.

increased supervision, which has been demonstrated to reduce errors, lower patient mortality, and improve quality of care.<sup>42</sup> These efforts in medical training may account for the association of decreased major complications in 2011 and 2012 in our data. However, other considerations are warranted, such as the possibility of improved training across faculty in microsurgical techniques.

We attempted to minimize referral bias by controlling for patient-level factors; however, residual bias may remain. The retrospective nature of this NSQIP analysis is not without limitations. First, more recent years of NSQIP have discontinued the use of variables allowing for determination of resident involvement in surgical cases, thus reducing the pool of cases to sample. Second, our results can only demonstrate the effect of the presence of a resident; however, the database does not inform researchers of the level of involvement or the year in training of the trainee, including whether the trainee is a resident or fellow. It is therefore not possible to determine whether the case was a “teaching” or “nonteaching” case, impeding our ability to determine if the resident was involved in planning, flap dissection, flap inset, microsurgical anastomoses, or closure. Third, although it has been demonstrated that success is dependent on the surgeon, we are unable to assess the skill or expertise of attending or trainee surgeons in these operations. Fourth, the NSQIP database tracks outcomes data for up to 30 days post-operatively, which would not capture long-term complications. Additionally, NSQIP does not track the specific type of free flap used for reconstruction, which may affect complications and outcomes. Lastly, information on hospital teaching status is not included in the database, thus we were unable to control for hospital-level effects. This may introduce a bias due to differences in case mix related to large academic centers that are more likely to involve residents. Additionally, the differences between high- or low-volume centers, which may have variable rates of flap failure, were not able to be controlled for.

## CONCLUSION

This, to our knowledge, is the largest review in the literature to study resident involvement regarding microsurgery outcomes. This study provides further evidence in support of the claim that resident involvement in microsurgery is safe and effective, with similar rates of major complications, minor complications, flap failure, and unexpected reoperation within 30 days compared with cases without resident involvement.

## DISCLOSURE

ACS NSQIP and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not

verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

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