Original Article

Non-intubated bronchoscopic tracheobronchial surgeries with electroencephalogram-monitored intravenous anesthesia: feasibility and outcomes

Yu Fang[1]^, Ching-Kai Lin[2,3], Zong-Han Yao[2,3], Hung-Jen Fan[2,4], Ya-Jung Cheng[1,5]^

[1]Department of Anesthesiology, National Taiwan University Hospital, Taipei; [2]Department of Medicine, National Taiwan University Cancer Center, Taipei; [3]Department of Internal Medicine, National Taiwan University Hospital, Taipei; [4]Department of Internal Medicine, National Taiwan University Biomedical Park Hospital, Hsin-Chu County; [5]National Taiwan University College of Medicine, Taipei

Contributions: (I) Conception and design: Y Fang, YJ Cheng; (II) Administrative support: Y Fang, YJ Cheng; (III) Provision of study materials or patients: Y Fang, YJ Cheng; (IV) Collection and assembly of data: Y Fang, CK Lin, ZH Yao, HJ Fan; (V) Data analysis and interpretation: Y Fang, CK Lin, YJ Cheng; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Ya-Jung Cheng, MD, PhD. Department of Anesthesiology, National Taiwan University Hospital, Taipei; National Taiwan University College of Medicine, Jen-Ai Road, Section 1, Taipei 10051. Email: chengyj@ntu.edu.tw.

Background: Anesthesia remains challenging for bronchoscopic tracheobronchial surgeries (BTS) involving surgical manipulations for central airway obstruction within shared airways. To provide complete airway use through intervention with spontaneous breathing without endotracheal tubes, monitored non-intubated anesthesia has been successfully applied with electroencephalogram-derived monitored total intravenous anesthesia. This study evaluated the feasibility and the outcomes of BTS with monitored non-intubated anesthesia. The factors associated with desaturation and complications were also analyzed.

Methods: Data from patients receiving non-intubated BTS performed between October 2019 and August 2022 were retrospectively collected. Intraoperative results and postoperative outcomes were analyzed.

Results: Data of 92 patients were collected. Supraglottic airways devices and high-flow nasal oxygen were used in 68 and 24 patients respectively. Surgery was successfully completed in 87 patients (94.6%), whereas three patients required conversion to intubation because of substantial bleeding. In total, 11% of patients experienced desaturation [oxygen saturation (SpO_2) <90%] for an average of 9 minutes. Unexpected admission to the intensive care unit (ICU) occurred in 12.2% (5/41) of patients from outpatient department and 7.8% (4/51) of hospitalization settings because of high-grade surgical bleeding. With comparable desaturation incidence, tracheal surgery had significantly longer desaturation times (14.5±6.9 min) than bronchial surgeries (5.8±2.6 min) did.

Conclusions: Monitored non-intubated anesthesia with spontaneous breathing is feasible for BTS, with high success rate, few complications, and rapid recovery. High-grade bleeding remains the most unpredictable risk for intraoperative desaturation and postoperative ICU admission, especially in tracheal obstruction cases.

Keywords: Bronchoscopic tracheobronchial surgery (BTS); intravenous anesthesia; electroencephalogram monitor (EEG monitor); spontaneous ventilation; complication

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^ ORCID: Ya-Jung Cheng, 0000-0001-9150-4690; Yu Fang, 0009-0001-2277-9241.

Introduction

Bronchoscopic interventions (BIs) combined with echography and computed tomography (CT) scans have increased in terms of numbers and complexity (1). Among these procedures, bronchoscopic tracheobronchial surgeries (BTS), such as tumor resection and foreign body removal, exhibit increasing procedural success and enhance survival in patients with central airway obstructions (2,3). However, anesthesia for shared airway and intra-airway manipulation for BTS remains a unique challenge for maintaining intraprocedural oxygenation (4-7). Mostly, anesthesia for BTS is induced with general anesthesia with endotracheal tube insertion (ETGA) (7,8) and muscle relaxants (9). However, ETGA might lead to perioperative bleeding, inoperability (10,11), loss of muscle tone (12), and postoperative pulmonary complications (13). According to the previous reports, anesthesia with spontaneous breathing without endotracheal tubes, i.e., non-intubated BTS (NIBTS), may be a beneficial alternative for maintaining oxygenation in every possible moment during interventions.

Without an endotracheal tubes, anesthesia could be precisely controlled with electroencephalogram (EEG)-derived anesthetic methods such as bispectral index (BIS) monitoring (14) and target-controlled infusion (TCI). Monitored anesthesia with adequate spontaneous ventilation, can prevent hypoxemia and severe hypercapnia, which delays recovery (9). However, manipulations for BTS are associated with extremely noxious stimulations and possibly complete airway obstruction. The risks of airway spasm, hypoxemia, and airway bleeding (15) are much higher than those in other BIs. Data regarding NIBTS are few, and the optimal strategy to manage patients receiving NIBTS is worthy of investigation. In this study, we collected the data of patients receiving BIS-monitored NIBTS and goaled to (I) assess the feasibility of NIBTS for managing tracheobronchial surgeries with monitored intravenous anesthesia; (II) clarify the factors including airway managements associated with major complications and recovery; and (III) analyze whether the location of lesions or the airway management strategy affected the intraoperative results and postoperative outcomes. We present this article in accordance with the TREND reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1935/rc).

Highlight box

Key findings

- Non-intubated tracheobronchial surgeries (NIBTS) are feasible and favorable with high success rate with new anesthetic strategy.

What is known and what is new?

- For NIBTS, oxygenation could be maintained with either iGel or high flow nasal oxygen (HFNO) cannula and spontaneous breathing under electroencephalogram-monitored intravenous anesthesia during bronchoscopic manipulations.
- Tracheal operations result in longer desaturation time than do bronchial surgeries.

What is the implication, and what should change now?

- Closely collaborative team is mandatory cause high grade bleeding remains the most unpredictable risk for intraoperative desaturation needing immediate, aggressive management.

Methods

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by Institutional Review Board of National Taiwan University Hospital (No. 202209042RINB) and individual consent for this retrospective analysis was waived. The data of patients receiving bronchoscopic tracheobronchial surgeries (including tumor resection, recannulation, stent implantation, and foreign body removal) with BIS-monitored intravenous anesthesia from October 2019 to August 2022 were retrospectively collected.

Anesthetic setting

Anesthesia was induced and maintained through TCI with Propofol infusion and intermittent bolus of midazolam, fentanyl, or alfentanil with noninvasive blood pressure, electrocardiogram (ECG), and oxygen saturation (SpO_2) monitoring. The depth of anesthesia was determined by BIS monitor with goaled level between 40 and 60 (16) and respiratory rates was maintained at 10–20 breaths per minute. From anesthetic induction to the end of the procedure, oxygen of 10 L/minute or adjusted as required was supplied through high flow nasal oxygen (HFNO) cannula or a supraglottic airway (SGA, i-gel) according to anesthesiologist' preference. 2% xylocaine injection through bronchoscopy after fiberoptic bronchoscopy (FOB) insertion was performed from vocal cords to bilateral bronchioles with a spray-as-you-go technique before starting NIBTS. All procedures were performed in hybrid operation room. Thus, post BTS cone beam CT was performed to detect possible pneumothorax or atelectasis. Patients were sent directly to

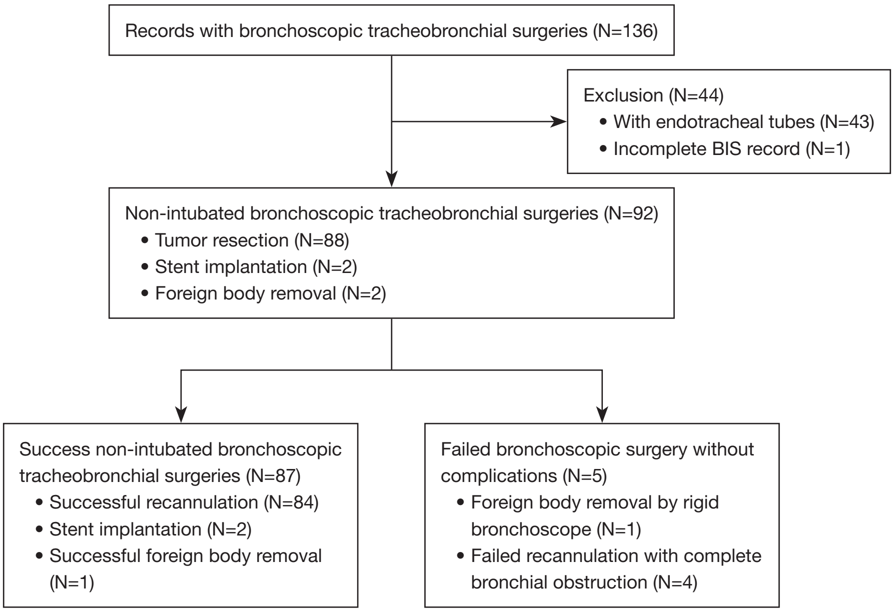

Figure 1 Flow diagram of patient selection. BIS, bispectral index.

the postanesthetic care unit (PACU) or intensive care unit (ICU) after their BIS reached above 85 after surgery.

Data collection

Data including age, sex, body mass index, inpatient or outpatient setting, American Society of Anesthesiologists (ASA) classification, operation performed were collected. BIS value, interval of desaturation (defined as SpO_2 of <90%), hypotension (mean blood pressure <65 mmHg or systolic blood pressure <90 mmHg), and recovery time in the PACU were obtained from electronic anesthesia and PACU records. Intraprocedural bleeding severity [according to Nashville Working Group (17)], conversion to tracheal intubation, resuscitation, unexpected admission, and the findings of postprocedural cone-beam CT scans were collected from procedural reports. Discharge summaries and medical records were collected to analyze the outcomes. Unexpected admission was defined as admission to the ICU without prearrangement.

Statistical analysis

Statistical analysis was performed using MedCalc version 20.118 (Ostend, Belgium; https://www.medcalc.org; 2022). A P value of <0.05 indicated significance. Findings are expressed as means ± standard deviation unless otherwise specified. Categorical data were tested using the chi-square test; otherwise, the parametric independent Student's *t* test was used. Correlations between continuous variables were analyzed using the Spearman correlation coefficient and logistic regression.

Results

Data collection and success rate of non-intubated tracheobronchial surgeries

As shown in *Figure 1*, of 136 patients receiving bronchoscopic tracheobronchial surgeries, 92 received scheduled NIBTS with monitored intravenous anesthesia. Successful surgeries were performed in 87 patients (87/92, 94.6%) with either an iGel or HFNO. Three patients were converted to intubation. Foreign body removal was failed in one patient. Rigid bronchoscopic removal was successfully performed on the next day. Failure of reestablishing the airways within complete bronchial obstruction were recorded on the other four cases due to inability to identify the possible direction.

Patient characteristics and preoperative settings

As shown in *Table 1*, iGels and HFNOs were applied for 68 and 24 patients, respectively. Patients receiving iGels

Table 1 Patient characteristics and preoperative settings in patients using iGel *vs.* HFNO for NIBTS

Variable	Total (n=92)	iGel (n=68)	HFNO (n=24)	P value
Age, years	60.9±11.3	61.6±11.8	58.8±11.8	0.80
Sex, male	59 (64.1)	41 (60.3)	18 (75.0)	0.20
Body height (cm)	162.4±9.6	162±10.5	162.8±6	0.73
Body weight (kg)	61.1±14.7	60.3±15.2	63.5±12.7	0.69
BMI (kg/m^2)	23.0±4.3	22.7±4.8	23.8±3.8	0.78
ASA				0.99
I	1 (1.1)	1 (1.5)	0	
II	56 (60.9)	42 (61.8)	14 (58.3)	
III	31 (33.7)	22 (32.4)	9 (37.5)	
IV	4 (4.3)	3 (4.4)	1 (4.2)	
Comorbidity				
Hypertension	59 (64.1)	44 (64.7)	15 (62.5)	0.85
CAD	5 (5.4)	2 (2.9)	3 (12.5)	0.08
COPD	17 (18.5)	11 (16.1)	6 (25.0)	0.34
Smoking	38 (41.3)	25 (36.8)	13 (54.2)	0.14
DM	16 (17.4)	12 (17.6)	4 (16.7)	0.92
Preoperative treatment				
No preoperative treatment	58 (63.0)	42 (61.8)	16 (66.7)	0.67
Endobronchial tumor excision	9 (9.8)	9 (13.2)	0 (0.0)	0.65
Tracheal stent implantation	25 (27.2)	17 (25)	8 (33.3)	0.43
BTS setting				
OPD	41 (44.6)	32 (47.1)	9 (37.5)	0.89
Admission	51 (55.4)	36 (52.9)	15 (62.5)	0.89

Data were expressed with mean ± standard deviation or n (%). HFNO, high-flow nasal oxygen; ASA, American Society of Anesthesia physical status classification; NIBTS, non-intubated tracheobronchial surgeries; BMI, body mass index; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; BTS, bronchoscopic tracheobronchial surgery; OPD, outpatient department.

or HFNOs did not differ in terms of ASA classification, previous airway treatments, or preoperative settings. For 25 patients (27.2%), bronchoscopic intraluminal removal of granulation tissue following stent implantation was performed to reestablish patent airways. As the details for types of stent, both were metallic, one at lower trachea, the other at middle trachea.

Perioperative data

As shown in *Table 2*, anesthetic, surgical results, intraoperative events, the recovery of patients from different settings, and postsurgical complications were demonstrated. The HFNO group had a significantly higher BIS range than did the iGel group, with comparable surgical types and similar success rates. Three of the 92 NIBTS patients transitioned to endotracheal tube intubation to secure airways and control the high-grade surgical bleeding. Two of the three were recovered after the removal of blood clots in airways and sent to ICU. One of the three required chest compression because of ventricular fibrillation. After resuscitation, the patient was sent to ICU and extubated on

Table 2 Anesthesia, surgical data, intraoperative events, postoperative recovery, and complications in NIBTS

Variables	Total (n=92)	iGel (n=68)	HFNO (n=24)	P value
Anesthesia				
Anesthesia time (min)	88.2±43.7	78±51.4	91.8±39.6	0.24
BIS levels				
Lowest BIS levels	35.3±7.9	34.6±8.1	38.5±6.5	0.0362*
Highest BIS levels	57.4±9.7	56.7±9.5	61.3±9.6	0.0449*
Surgery				
Surgical time (min)	72.2±40.7	68±49.3	73.6±36.7	0.97
Tumor excision	88 (95.7)	65 (95.6)	23 (95.8)	0.75
Cryoprobe only	71 (80.7)	50 (76.9)	21 (91.3)	0.97
Cryoprobe + APC	2 (2.3)	0	2 (8.7)	
Cryoprobe + forceps	7 (8.0)	7 (10.8)	0	
Cryoprobe + electrocautery (snare)	1 (1.1)	1 (1.5)	0	
Cryoprobe + balloon dilatation	7 (8.0)	7 (10.8)	0	
Stent insertion	2 (2.2)	2 (2.9)	0	0.40
Foreign body removal	2 (2.2)	1 (1.5)	1 (4.2)	0.12
Lesion location				>0.99
Trachea	37 (40.2)	27 (39.7)	10 (41.7)	
Bronchus	55 (59.8)	41 (60.3)	14 (58.3)	
Surgical outcomes				
Successful recannulation (n, success rate)	81 (81/85, 95.3%)	62 (62/63, 98.4%)	22 (22/22, 100%)	0.54
Repeated bronchoscopic recannulation within 7 days	3	3 (4.8)	0	0.28
Successful stent insertion (n, %, success rate)	2, 2.2%, 100%	2, 2.9%, 100%	0	0.40
Foreign body removal (n, %, success rate)	1, 1.1%, 50%	1, 1.5%, 100%	0	0.55
Intraoperative events				
Desaturation	10 (10.9)	6 (8.8)	4 (16.7)	0.29
Desaturation time (min)	9.3±6.4	9.5±6	9±7	0.94
Hypotension	47 (51.1)	37 (54.4)	10 (41.7)	0.29
Hypotension time (min)	14.8±10.3	13.7±9.8	18.6±11.3	0.39
Complications				
Bleeding				0.17
Minimal	44 (47.8)	28 (41.2)	16 (66.7)	
Grade 1	19 (20.7)	17 (25.0)	2 (8.3)	
Grade 2	25 (27.2)	22 (32.4)	3 (12.5)	
Grade 3	4 (4.3)	1 (1.5)	3 (12.5)	

Table 2 (*continued*)

Table 2 (*continued*)

Variables	Total (n=92)	iGel (n=68)	HFNO (n=24)	P value
Stridor	1 (1.1)	1 (1.5)	0	0.55
Conversion to tracheal intubation	3 (3.3)	1 (1.5)	2 (8.3)	0.71
Resuscitation with chest compression	1 (1.1)	1 (1.5)	0	0.55
Recovery				
With preoperative OPD setting	41	32	9	
Discharge from PACU (n=27)	27 (65.9)	22 (68.8)	5 (55.6)	0.54
PACU stay (min)	38.1±14.9	39.4±15.7	31.0±4.6	0.13
Planned admission to ICU	9 (22.0)	8 (25.0)	1 (11.1)	0.38
Unexpected admission to ICU	5 (12.2)	2 (6.3)	3 (33.3)	0.03*
With preoperative hospitalization setting, n	51	36	15	
Through PACU to ward, n (%)	31 (60.8)	18 (50.0)	13 (86.7)	0.02*
PACU stay (min)	40.1±10.0	40.1±10.0	31.8±13.4	0.02*
Planned admission to ICU	16 (31.4)	15 (41.7)	1 (6.7)	0.01*
Unexpected admission to ICU	4 (7.8)	3 (8.3)	1 (6.7)	0.85
ICU stay (days)	2.6±2.6	2.4±2.3	3.4±3.4	0.11
Complications	92	68	24	
Pneumonia	1 (1.1)	1 (1.5)	0	0.55
Sepsis	1 (1.1)	1 (1.5)	0	0.55
Hemoptysis, airway bleeding	7 (7.6)	5 (7.4)	2 (8.3)	0.89
Atelectasis	1 (1.1)	1 (1.5)	0	0.55
Stridor	1 (1.1)	1 (1.5)	0	0.55
Severe throat pain	1 (1.1)	0	1 (4.2)	0.09
30-day mortality	1 (1.1)	1 (1.5)	0	0.55

Data were expressed with mean ± standard deviation or n (%) unless otherwise indicated. Desaturation was defined as SpO_2 <90%. Hypotension was defined as mean blood pressure <65 mmHg or systolic blood pressure <90 mmHg. *, for all pairwise multiple comparison procedures (Holm-Sidak method) with significance level =0.05. NIBTS, non-intubated tracheobronchial surgeries; HFNO, high-flow nasal oxygen; APC, argon plasm coagulation; BIS, bispectral index; ICU, intensive care unit; PACU, postanesthesia care unit; OPD, outpatient department; SpO_2, oxygen saturation.

postoperative day 4. Nine cases were unexpectedly admitted to the ICU because of the necessity for close observation and prompt management of further bleeding.

Recovery data were analyzed with different preoperative settings. In total, 27 of 41 (65.6%) patients were discharged from their preoperative settings. The length of stay in the PACU was significantly shorter for patients receiving HFNO (P=0.02). The rate of unexpected ICU admission did not significantly different across different preoperative settings [12.2% for outpatient department (OPD) setting *vs.* 7.8% for hospitalization setting, P=0.48].

Postoperative complications were also analyzed. Hemoptysis or postoperative airway bleeding occurred in seven patients without tracheal intubation during ICU stay. Their average ICU hospitalization duration was 2.6±2.6 days.

Differences in tracheal or bronchial surgeries

As shown in *Table 3*, with comparatively high success rates, management of tracheal lesions was associated with

Table 3 Intraoperative events and postoperative outcomes of tracheal and bronchial surgeries in NIBTS

Intraoperative events	Trachea (n=35)	Bronchus (n=57)	P value
Hypotension case	19 (54.3)	27 (47.4)	0.52
Accumulative hypotension time (min)	16.6±10.3	13.5±10.5	0.22
Desaturation case	4 (11.4)	6 (10.5)	0.89
Accumulative desaturation time (min)	14.5±6.9	5.8±2.6	0.02*

Data were expressed with mean ± standard deviation or n (%). *, statistically different by *t*-test with significance level =0.05. NIBTS, non-intubated tracheobronchial surgeries.

a comparable desaturation incidence (about 10%) but a significantly longer accumulative desaturation time.

Discussion

Our results showed that monitored NIBTS with spontaneous ventilation could be successfully performed with limited complications. A total of 68 of 92 (73.9%) patients were discharged from the OPD or returned to their ward from the PACU after bronchoscopic tracheobronchial surgeries. Our study supports the feasibility of monitored NIBTS. The high success rate suggests that without an existing endotracheal tube, bronchoscopists had more flexibility to utilize different probes.

The risk of postoperative bleeding remains the main cause of unexpected ICU admission. According to our results, 14.1% (13/92) of patients were sent to the ICU for close observation and prompt response to further bleeding. These patients did not significantly differ by the preoperative setting. As cryoprobes are frequently applied for tracheobronchial tumor removal, it is reported a risk factor for airway bleeding (18). In this study, intraoperative desaturation was mainly associated with airway bleeding and its consequent management, such as balloon compression, which can block the airways for minutes.

Comparable intraoperative and postoperative outcomes for NIBTS were demonstrated using iGel or HFNO. The predominant use of iGels in this study might have resulted from the SARS-CoV-2 outbreak. The disposable devices with plastic covering are presumed to limit aerosol and secretion spread (19). Our results suggested of applications of i-Gels offer direct glottic view (20) and feasibility for variable probes in tumor resection. The feasibility of HFNO for NIBTS is also consistent with the results of bronchoscopy research (21-23) and with a shorter length of PACU stay. HFNO may have the advantage of causing minimal stress during airway management and preventing atelectasis (24). However, randomized controlled studies should be performed in the future.

Desaturation occurred in 10 (10.8%) cases in our study. The incidence of desaturation was much lower than that in previous reports using different interventions (25,26). Maintaining spontaneous breathing may benefit oxygen delivery without interrupting ventilation in every possible moment during manipulations. However, precise anesthetic depth is crucial for keeping spontaneous breathing. The locoregional anesthesia added with bronchoscopic spray of local anesthetics play an important part of anesthesia for smooth breathing during BTS. BIS monitor helps to optimize the anesthetic levels, avoid too deep anesthesia which inhibit spontaneous breathing as well as indicate the timing of repeated locoregional anesthesia. However, for patients with high ASA classification or those requiring a difficult procedure, ECMO may be the optimal choice or warrant preparation for standby (27). Moreover, our results indicate that tracheal operations result in longer desaturation than do bronchial surgeries regardless of their high success rate, which might imply that lesions at trachea are riskier due to complete airway obstruction and smaller respiratory reservoir. NIBTS may facilitate the bronchoscopic management for tracheal pathology (28) and enhance the recovery without residual muscle relaxation.

Conclusions

In conclusion, monitored NIBTS with spontaneous breathing is feasible, with a high success rate, few complications and rapid recovery. With precise anesthesia and close team cooperation, NIBTS can be performed uneventfully with faster recovery using either supraglottic airways or HFNO. However, tracheobronchial surgeries have a high risk of unpredictable procedural bleeding. Cooperation between endoscopists and anesthesiologists is required for more rapid response to high-grade bleeding, especially for tracheal lesions.

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Footnote

Reporting Checklist: The authors have completed the TREND reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1935/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1935/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1935/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by Institutional Review Board of National Taiwan University Hospital (No. 202209042RINB) and individual consent for this retrospective analysis was waived.

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