Value of Virtual Surgical Planning: Time-Driven Cost Analysis in Head and Neck Osseous Reconstruction

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Arjun Dinesh, MS[1]; Kelly Michele Malloy, MD, MBA, FACS[2]; Keith A. Casper, MD[2]; Molly Heft Neal, MD[2]; Chaz Stucken, MD[2]; Steven Chinn, MD, MPH, FACS[3]; David WA Forner, MD, MSc, FRCSC[2]; Pratyusha Yalamanchi, MD, MBA[2]

[1] Case Western Reserve University School of Medicine, Cleveland, OH
[2] Department of Otolaryngology–Head and Neck Surgery, University of Michigan, Ann Arbor, MI
[3] Department of Otolaryngology–Head and Neck Surgery, University of Pittsburgh, Pittsburgh, PA

INTRODUCTION

Virtual Surgical Planning (VSP) uses preoperative imaging and computer-assisted design/manufacturing to generate cutting guides and patient-specific plates for maxillary and mandibular free flap reconstruction.

Potential advantages: improved precision, ability to perform complex reconstructions, and reduced intraoperative decision-making.

Concern: additional costs from guides, plates, and engineering time.

Key question: Do these added costs translate into greater value using rigorous methodology such as time-driven activity-based costing (TDABC)?

METHODS

Design: Retrospective 1:1 matched cohort (2018–2024) of osseous free flap reconstructions across 2 tertiary centers (n=98).

TDABC Framework (applied at one institution):
Institutional pilot program (2016) integrated TDABC into service lines with outcome tracking and redesign interest.

Episode of care defined: operative + postoperative admission (up to 30-day readmission).

Process mapping: Modified Delphi technique to chart each activity (pre-op, OR, PACU, inpatient care).

Resource costing:
Personnel: based on logged time × salary/benefits (FTE).
Physicians: estimated using work-RVUs.
Supplies: itemized from institutional chargemaster.
Equipment/overhead: depreciation and indirect costs incorporated into *capacity cost rate (CCR)* for each setting (OR, ICU, ward).

Calculation: Total cost = Σ (CCR × time for each resource).

Analysis: Outcomes: operative/ischemia time, complications, margin status, plate removal, cost.
Cost drivers analyzed via generalized linear mixed model.

RESULTS

Table 1: Patient Demographics and Clinical Characteristics

Variable	VSP Group (n=49)	Conventional Group (n=49)
Demographics		
Sex, Male, n (%)	35 (71.4%)	37 (75.5%)
Marital Status		
Single, n (%)	8 (16.3%)	7 (14.3%)
Married/Partnered, n (%)	41 (83.7%)	42 (85.7%)
Free Flap Type, n (%)		
Fibula	31 (63.3%)	11 (22.4%)
Scapula/Osteocutaneous Lat Dorsi	9 (18.4%)	25 (51.0%)
Forearm/Other	9 (18.4%)	13 (26.5%)
Institution, n (%)		
Michigan	28 (57.1%)	29 (59.2%)
Vanderbilt	21 (42.9%)	20 (40.8%)
ECOG Performance Status		
0-1, n (%)	46 (93.9%)	46 (93.9%)
2+, n (%)	3 (6.1%)	3 (6.1%)
Clinical T Stage		
T1-T2, n (%)	7 (14.3%)	8 (16.3%)
T3-T4+, n (%)	42 (85.7%)	41 (83.7%)
Clinical N Stage		
N0-N1, n (%)	30 (61.2%)	31 (63.3%)
N2+, n (%)	19 (38.8%)	18 (36.7%)
Tumor Histology		
Squamous Cell Carcinoma, n (%)	41 (83.7%)	43 (87.8%)
Other, n (%)	8 (16.3%)	6 (12.2%)

Operative time: VSP vs. Conventional — 566.9 vs. 558.9 min (p = 0.775).

Bony segments: Higher with VSP (p = 0.002).

Ischemia time: VSP vs. Conventional — 89.1 vs. 92.3 min (p = 0.696).

Postoperative outcomes: No significant differences in complication rates, oncologic margins, or plate removal.

Cost of care (TDABC):
VSP: $40,500 ± 15,400
Conventional: $38,600 ± 21,860 (p = 0.15)

Cost drivers (GLMM, R^2 = 0.73):
Shorter operative time significantly lowered cost (p < 0.05).
Additional independent cost drivers**:** length of stay, return trips to OR, and number of free flaps.

Table 1: Clinical Outcomes Comparison

Outcome	VSP vs Control	P
Operative Characteristics		
Operative Time (min)		0.775
Mean (SD)	566.9(118.4) vs 558.9(152.9)	
Ischemia Time (min)		0.696
Mean (SD)	89.1(29.1) vs 92.3(33.6)	
Bony Segments		**0.002**
Mean (SD)	1.81(0.91) vs 1.33(0.63)	
Hospital Days		0.947
Mean (SD)	8.1(4.1) vs 7.5(2.9)	
Postoperative Complications		
Any Complication, n/N	9/49 vs 10/49	1.000
(%)	18.4% vs 20.4%	
Free Flap Complication, n/N	1/21 vs 0/20	1.000
(%)	4.8% vs 0.0%	
Return to OR, n/N	8/21 vs 6/20	0.828
(%)	38.1% vs 30.0%	
Complication Grade	3.2 vs 2.9	0.741
Mean (SD)	(1.3) vs (1.5)	
Oncologic Outcomes		
Positive Margins, n/N	5/40 vs 9/44	0.494
(%)	12.5% vs 20.5%	
Cancer Recurrence, n/N	10/46 vs 16/49	0.336
(%)	21.7% vs 32.7%	
Long-term Outcomes		
Plate Removal, n/N	9/49 vs 8/49	1.000
(%)	18.4% vs 16.3%	
Osteoradionecrosis, n/N	15/49 vs 8/49	0.153
(%)	30.6% vs 16.3%	
Death, n/N	9/29 vs 7/32	0.679
(%)	31.0% vs 21.9%	

Bold indicates $p < 0.05$

CONCLUSIONS

VSP enables more complex reconstructions without increasing ischemia time, complications, or plate removal.

Cost analysis showed VSP was not a significant driver of total care cost; operative time, LOS, and complications had greater influence.

VSP supports value-based care by allowing surgical precision and complexity without added financial burden.