We describe the design and clinical impact of 3 intraoperative pathways: transcervical (TC) resection of oral cavity neoplasia, transmandibular (TM) resection of oral or oropharyngeal neoplasia, and laryngopharyngectomy (LP), all with radial forearm free-flap (RFFF) reconstruction. This article details the design of each pathway that projects intraoperative flow and teamwork. The impact of the pathways is analyzed through descriptive statistics for procedure and case lengths in each pathway, against target pathway times, and in inferential comparison with grouped pre-pathway times. Summary conclusions include time and action efficiencies, projections for further analysis, and directions for research and practice.

**RESULTS**

The targeted goals of decreased procedure time, representing anesthesia time, and decreased overall case length were achieved (Table 2). Aggregate pathway mean times (N=21) were 10.93 hours for procedure length and 12.85 hours for case length. The aggregate postpathway case lengths are statistically significantly different from the prepathway case lengths. The pathway mean case length also
PATIENTS AND METHODS

Our academic medical center uses 3 intraoperative clinical pathways to manage resource use and streamline care for patients undergoing head and neck resections with RFFF reconstruction. These intraoperative pathways were developed in parallel with a head and neck clinical management pathway. The results of this pathway are reported elsewhere. The intraoperative pathway was separated to enable greater specificity in work and resource redesign to improve patient care.

These 3 intraoperative pathways were the first for the Department of Otorhinolaryngology/Head and Neck Surgery, Hospital of the University of Pennsylvania. Our institution has been performing microvascular reconstruction in patients undergoing head and neck surgical procedures for 10 years. Head and neck resection with reconstruction has been viewed as difficult to standardize because of extended-length cases with multiple components and individual anatomic and design elements. The TC resection of oral cancers, the TM resection of oral and oropharyngeal cancers, and LPs, all with RFFF reconstruction, were selected for pathways because of the high positive prepathway profile of these operations and because of the head and neck team members (A.A.C., A.N.G., A.D., G.S.W., and R.S.W.) within the intraoperative environment.

The goal of the design was to create an algorithm that would specify a time-action pathway with time- and discipline-specific resources and actions to maintain patient outcomes and potentially achieve improved outcomes by shortening case length. Improved patient outcomes were defined as decreased time in the operating room (OR) and decreased anesthesia time. Cost savings and enhanced clinical and nonclinical staff satisfaction were assumed to be imbedded in achieving patient outcomes.

DESIGN

The 3 intraoperative head and neck surgery pathways were designed schematically by an interdisciplinary team (A.A.C., A.N.G., A.D., G.S.W., and R.S.W.). They were part of a larger institutional initiative that had 5 goals: specialty-focused intraoperative pathway development; reduce unnecessary variation and use in materials, durable equipment, medications, staff, and time; increase accuracy, quality, completeness, and timeliness of all resources used; increase direct patient care for nursing staff; and increase throughput to decrease cost per case.

The primary attending head and neck reconstructive surgeon (A.A.C.), the attending anesthesiologist (A.N.G.) for the OR section, and the primary circulating nurse (A.D.) for patients undergoing head and neck procedures formed the core team. Attending head and neck surgeons (A.A.C., G.S.W., and R.S.W.), attending anesthesiologists (A.N.G. and others), perioperative nurses (A.D. and others), and perioperative administrators reviewed the pathways during development, contributing to the design as necessary. The specific goals of the head and neck core team were to achieve standardized time actions for surgery, anesthesia, and nursing; to standardize the instrument sets for each pathway; to create a routine environmental setup; and to accommodate the individual components of each patient’s operation (eg, the extent of the tumor; anatomic variation, such as neck exposure; and unilateral vs bilateral neck dissection). The pathway goals assumed synchronous flap harvest. This assumption added the potential variation of team surgery coordination.

The pathways plan progression of the case by timed actions for surgical, anesthesia, and nursing teams. The team member responsibilities were detailed in schematic form for each pathway. A distillation of these roles and responsibilities is presented in Table 1. The pathway is predicated on a single nursing team with 2 staff scrubbed and 2 surgical teams as necessary to resect the tumor and reconstruct the defect. This team structure was in place before pathway implementation and was systematized by the pathway.

A basic pathway schema was developed for consistency (Figure). Case length was defined as time into room to time out of room. Procedure length was defined as time from skin incision to time dressings were placed on the patient. The intraoperative environment was examined and resource needs delineated. Instrument set development was a major focus for resource use and clinician satisfaction. Eligibility criteria included neoplasia of the oral cavity, hypopharynx, oropharynx, or soft tissues of the head and neck. Tumor stage and radiation status were not part of the eligibility criteria. Patients were ineligible if they had skull base tumors; bone, pectoralis, or latissimus dorsi flaps; or lateral thigh or rectus abdominus free flaps. The default criterion for the pathways was premature termination or a canceled procedure.

Continued on next page

achieved the target time for the TC pathway (mean, 12.85 hours; SD, 1.76 hours; range, 10.50-16.60 hours), undercutting the target times for the TM and LP pathways. The mean time for procedure length was 10.93 hours (SD, 2.18 hours; range, 5.80-15.57 hours); and for ischemia, 3.28 hours (SD, 0.77 hours; range, 1.56-4.67 hours).

The aggregate postpathway procedure lengths are statistically significantly different from the prepathway procedure lengths (mean, 10.93 vs 12.50 hours; t test; P =.009). The postpathway ischemia times are not statistically significantly different from the prepathway ischemia times at P =.05 (mean, 3.28 vs 3.58 hours; t test; P =.07). The mean ischemia times did, however, show a clinical trend toward a decline of 0.3 hours postpathway.

Transcervical pathway procedure and case lengths averaged 10.48 and 12.33 hours, respectively. This mean case length was shorter than the target of 13 hours. In addition, the procedure length was statistically different from the prepathway procedure length (mean, 10.48 vs 12.37 hours; t test; P =.02). The case length was also statistically different from the prepathway case length (mean, 12.33 vs 14.45 hours; t test; P =.009). The TM and LP pathways had limited enrollment. Prepathway and postpathway analyses were not statistically valid or significant because of the small subsample sizes. Transmandibular pathway procedure and case lengths averaged 11.19 and 13.32 hours, respectively. This is shorter than the target of 14 hours. Laryngophar...
The pathway schematics are formatted left to right, starting at time minus 30 minutes, with OR setup and temperature controlled from the night before. Team responsibilities are described along the horizontal axis for the surgeon, the anesthesiologist, and the nurse. These times are sequenced by actions across the top of the pathway schematic to summarize the actions taken by team members that are listed on the vertical axis of the actual pathway schematic (Figure). The pathway is completed at the point the room is readied for the next patient. Target pathway times were determined by consensus because no benchmarking data were available. Case length was estimated from the OR’s surgical database for historically derived averages. The historical time for TC resection was 16 hours; TM resection, 17 hours; and LP, 19 hours. These times were used primarily for design purposes. The target pathway times for case length, developed by the pathway team, are 13 hours for TC resection, 14 hours for TM resection, and 15 hours for LP.

ENROLLMENT

Pathway implementation occurred in March 1998. Twenty-one patients undergoing reconstructive surgery, for the first year after implementation, were enrolled in the pathways for TC resection (n=11), TM resection (n=8), or LP (n=2), with RFFF reconstruction for all. Data for 4 patients were incompletely recorded, and could not be used in analysis. These patients are analyzed using descriptive statistics and qualitative variables for work flow and team satisfaction. Prepathway averages from a convenience sample of 30 surgical procedures (16 TC resections, 7 TM resections, and 7 LPs) performed in the 2 years preceding pathway implementation are used for comparison. Prepathway and postpathway surgical procedures were performed by the same team of surgeons (A.A.C., G.S.W., and R.S.W.), using the same simultaneous flap harvest techniques.

Three times are used for comparison: ischemia time during microvascular reconstruction, procedure length, and case length. Ischemia time was recorded as the time (in minutes) for action 2 on the pathway (Figure). Procedure length was recorded in minutes from skin incision to dressing. Pathway case length, as noted earlier, was defined as time into the OR to time out of the OR, inclusive and recorded in minutes. All recorded times were converted to hours.

#### Table 1. Team Member Responsibilities*

<table>
<thead>
<tr>
<th>Pathway Variable</th>
<th>Anesthesia</th>
<th>Nursing</th>
<th>Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preinduction</td>
<td>Check patient ID and allergies; assess airway; verify flap site with surgeon; place monitoring equipment; place IV catheter and start antibiotic therapy</td>
<td>Confirm room setup with fluid mattress to OR table; check patient ID, allergies, medication record, and consent forms for surgery and blood transfusion; confirm flap site with surgeon; team with anesthesiologist to bring patient into room; assess skin integrity and position; open sterile instrument packs/verify sterility; perform instrument setup; start counts; start data entry; maintain quiet</td>
<td>Bring imaging films, office notes, consent forms, and pathology report</td>
</tr>
<tr>
<td>Intubation</td>
<td>Perform induction and intubation; verify and secure airway; provide eye protection; monitor hemodynamic status</td>
<td>Assist anesthesia team; place Foley catheter; continue setup; continue counts; data entry; maintain quiet</td>
<td>Present for induction</td>
</tr>
<tr>
<td>Preoperative</td>
<td>Place A-line catheter; start a second IV catheter if necessary; use a convection warming blanket</td>
<td>Assist anesthesia team; gown and glove surgical team; assist with concurrent procedures as necessary; call family lounge; continue data entry; lower room temperature</td>
<td>Neck incision and neck dissection(s)</td>
</tr>
<tr>
<td>Resection</td>
<td>Volume replacement as needed; muscle relaxation in accordance with surgical needs</td>
<td>Monitor sterility of tables; continue data entry</td>
<td>Tumor resection; tracheal tube placement; flap procurement; skin graft harvest; vessel preparation in neck; check margins; detach flap</td>
</tr>
<tr>
<td>Reconstruction</td>
<td>Assist with exchange touffed tracheal tube vs reinforced anode tube; confirm airway; provide ABGs as necessary; begin systemic infusion of heparin sodium</td>
<td>Apply test-tube cuff; check blood glucose level as necessary by fingertip method; assist with skin graft; prepare microscope for microvascular anastomosis (video camera in place); activate SICU bed request</td>
<td>Anchor flap; create microvascular anastomosis; close surgical site</td>
</tr>
<tr>
<td>Transfer</td>
<td>Organize catheters and equipment for transfer; direct transfer to SICU bed after patient has spontaneous ventilation through tracheotomy; accompany patient to SICU; exchange medications</td>
<td>Assess skin integrity with surgeons; call SICU and confirm bed; final count; call room cleaning; final call to family; data entry complete; manage room turnover</td>
<td>Apply cast to flap site and ointment to surgical site; activate postoperative pathway orders; remove imaging films and office notes</td>
</tr>
</tbody>
</table>

*ID indicates identification; IV, intravenous; OR, operating room; ABGs, arterial blood gases; and SICU, surgical intensive care unit.
Organizational analysis and redesign of the health care industry is an omnipresent topic in clinical literature without rigorous traditional research to support specific uses. Many institutions have redesigned work groups and processes, based largely on organizationally perceived cost-benefit analyses, with and without the assistance of external consultants. Historically, processes with little tolerance for error were schematized (eg, advanced cardiac life support protocols). Resource and time-intensive operative and other invasive procedures requiring anesthesia frequently lend themselves to redesign. Goals most often include standardized resources, such as instruments, and schematized time and action algorithms. Processes selected for redesign are generally high volume, high resource, or high cost within an organization or subspecialty.

Perioperative and invasive procedure redesign initiatives reported in medical and nursing literature include the following: frontal sinus obliteration, head and neck oncologic surgery and chemotherapy, ambulatory surgery, carotid endarterectomy, radical prostatectomy, knee replacement, and elective colon resection. The reports consistently refer to goals of improved resource use without adverse effects to patients for procedures that were clinically predictable intraoperatively and perioperatively. Reported pathways excluded intraoperative processes or procedures. Our intraoperative pathways afford enhanced time and action efficiency to streamline the care of patients undergoing head and neck procedures. The mean aggre-
gate case length achieved the target time for the TC pathway. This was the most limited of the 3 procedure target goals. This suggests that the process of intraoperative pathway implementation is valuable and that performance improvement in time-action efficiencies can be achieved. It also suggests that the accommodation for procedure may not be necessary if approaches to resection and to reconstruction are appropriately matched. Our experience supports the notion that complex operations with multiple components may be standardized. We acknowledge the need for allowances that reflect tumor extent, anatomic variation that may limit the efficiency of resection (eg, neck exposure, obesity, or another comorbidity), possible metastatic disease that requires bilateral neck dissection, and free-flap design elements.

Further analysis of cost benefits is pending acquisition of information processing systems for cost per OR hour and cost per case. Comparative analysis is limited by the nature of available literature and by the extent of our database. Future research that builds information management systems and enables detailed financial analysis within the context of hospital stay and billing returns will add an additional dimension to this area of outcomes research and performance improvement.

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From the Departments of Otorhinolaryngology/Head and Neck Surgery (Drs Chalian, Goldberg, Weinstein, and Weber) and Anesthesia (Dr Gottschalk), and the Nursing Service, School of Nursing (Dr Kagan and Ms Dakunchak), Hospital of the University of Pennsylvania, Philadelphia. Dr Goldberg is now with the Department of Otolaryngology/Head and Neck Surgery, University of California, San Francisco; and Dr Gottschalk is now with the Department of Anesthesiology and Critical Care, The Johns Hopkins University, Baltimore, Md.

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Corresponding author: Ara A. Chalian, MD, Department of Otorhinolaryngology/Head and Neck Surgery, Hospital of the University of Pennsylvania, 5 Silverstein, 3400 Spruce St, Philadelphia, PA 19104-4283 (e-mail: chaliana@uphs.upenn.edu).

REFERENCES