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Neurosurgical checklists: a review

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Morbidity due to avoidable medical errors is a crippling reality intrinsic to health care. In particular, iatrogenic surgical errors lead to significant morbidity, decreased quality of life, and attendant costs. In recent decades there has been an increased focus on health care quality improvement, with a concomitant focus on mitigating avoidable medical errors. The most notable tool developed to this end is the surgical checklist. Checklists have been implemented in various operating rooms internationally, with overwhelmingly positive results. Comparatively, the field of neurosurgery has only minimally addressed the utility of checklists as a health care improvement measure. Literature on the use of checklists in this field has been sparse. Considering the widespread efficacy of this tool in other fields, the authors seek to raise neurosurgical awareness regarding checklists by reviewing the current literature.
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In 1980, Trunet and colleagues[62] estimated that approximately 41% of hospitalized patients were admitted due to iatrogenic disease. Gawande and colleagues[29] postulated that of all hospital admissions nationally, 3% resulted in adverse events and 50% of these events were preventable. In 2000, the Institute of Medicine published *To Err is Human: Building a Safer Health System*. That publication suggested that there were at least 90,000 deaths annually attributed to avoidable medical errors.[5,38] Several studies have quantified the summative costs of medical errors.[29,58–62,64] In Utah alone, a 1999 study estimated that the total cost due to adverse medical events totaled approximately US $600,000 for 459 adverse events.[60] A similar study in New York documented mortality rates of 13.6% and total costs upward of US $800 million for adverse events that year.[5,35] The prevention of these avoidable medical errors has contributed to the evolving interest in quality improvement measures, with heavy emphasis on surgical checklists.

In 2009, Haynes et al. published the WHO Surgical Safety Checklist.[32] The 19-item checklist sought to address infection prevention and anesthesia-related complications in surgery. In his 2009 book, Atul Gawande espoused the utility of the WHO checklist in error prevention.[28] Imported from the field of aviation, his work identifies areas of routine tasks prone to human error and identifies corrective measures to prevent this error. His perspective identifies the intrinsic human fallibility and the inherent inability to provide consistently flawless outcomes with total reliance on individual performance.

Medicine has seen an explosion in checklists aimed at improving patient safety. Whereas general surgery[4,7,9,11,16,18,19,26,48–50] and anesthesia[8,31,42,43,46] have published extensively on the use of checklists, neurosurgery has been less productive. Perhaps the product of a smaller field, the need for standardizing preoperative activities is of paramount importance in the high-risk world of neurosurgery. In an effort to advance the use of checklists in neurosurgical

Abbreviations used in this paper: DBS = deep brain stimulation; ICP = intracranial pressure; NASS = North American Spine Society; OR = operating room; SURPASS = Surgical Patient Safety System.

practice, we provide a summary of previously published neurosurgical operative checklists. It is our hope that this repository of current literature, and the evidence behind it, may expand the use of checklists in neurosurgery.

Methods

The MEDLINE and PubMed records were searched to identify all published studies pertaining to surgical safety checklists in all surgical fields and in those specific to neurosurgery. The following terms: quality improvement, surgical checklists, preprocedural checklists, vascular neurosurgery checklist, functional neurosurgery checklist, pediatric neurosurgery checklist, oncology neurosurgery checklist, spine surgery checklist, and wrong-site surgery were used as medical subject heading terms and text words. The reference lists of these articles were examined to identify additional relevant research.

Results

Surgical Checklists

The presurgical time-out has repeatedly been shown to decrease wrong-site surgery and OR sentinel events and has been endorsed by powerful organizations such as the WHO and the Joint Commission.[32,44] A landmark study in 2009 by Haynes et al.[32] introduced the WHO Surgical Safety Checklist to OR staff in 8 international hospitals. Prospective data from 7688 patients showed a decreased rate of death (from 1.5% to 0.8%) and decreased inpatient complications (from 11% to 7%) after implementation of the checklist. This study furthered the role of the checklist in modern medicine due to the list's brevity and low cost, as well as its direct link to decreased mortality and morbidity.

The following year, de Vries et al. published the results of their SURPASS checklist, which was also studied using a multicenter, prospective method with 8207 patients.[20] However, unlike the Haynes checklist, which was limited to the OR, the SURPASS checklist followed general surgery patients from admission to discharge. Decreases in the death rate (from 1.5% to 0.8%) and complication rate (from 27.3% to 16.7%) were noted. Additionally, complication rates for patients with 80% or more of the checklist completed was significantly lower than for patients with less than 80% of the checklist completed (7.1% compared with 18.8%). This study demonstrated the efficacy of a checklist devoted to the complete surgical pathway, despite its length and difficulty in implementation.

The checklist is an effective tool in the mitigation of iatrogenic morbidity. Several specialties have made strides with checklists. Table 1 summarizes validated checklists published in other medical and surgical fields and their results.

Neurosurgical Checklists

In the neurosurgical community, checklists have been evaluated in several areas, including DBS, aneurysm treatment, and spine surgery, as noted in Table 2.[13,21,39,44,55,57] To date, no direct link between neurosurgical checklists and patient safety has been published. This lack of evidence provides motivation for the field as a whole to integrate checklists into the standard of care and to prove the worth of these lists, as other fields have.

In making such an effort, neurosurgery can seek to use general surgical checklists, such as the many variations of the nearly ubiquitous time-out, or procedure- and specialty-specific checklists. Neurosurgery is a diverse field with a wide range of procedures, including delicate brain dissection, DBS, complex spinal deformity correction, and endovascular therapies. Each of these subspecialties entails individualized patient and surgical factors that require meticulous attention to detail. In an effort to advance the use of checklists in neurosurgical practice, we provide a summary of previously published checklists applicable to certain neurosurgical procedures in Table 2.

General Neurosurgery. To date, 3 studies have been published detailing surgeons' experience using checklists for general neurosurgical procedures. Da Silva-Freitas et al.[14] evaluated their modified version of the WHO surgical safety checklist in 44 neurosurgical operations and identified 51 possible sentinel events. Their checklist helped prevent 88% of possible errors prior to initiation of surgery. Matsumae et al.[45] implemented a similar checklist and used an on-duty safety nurse to ensure that all safety practices were being met.

Lyons[44] has published perhaps the most robust neurosurgical checklist experience. This author published 8 years of data with an operative checklist, the goal of which was to prevent wrong patient, wrong site, and wrong surgery, summarized in Table 3. Lyons found that in 6313 operative checklists for 6345 patients, compliance was 99.5%. However, he was unable to document a reduction in the number of wrong-site or wrong-patient surgeries due to the infrequency of these incidents. One unique facet of the Lyons checklist was who administered it. Whereas many checklists are completed by OR nurses, the Lyons checklist has a place for the surgeon's signature prior to every case.

Functional Neurosurgery. In recent decades, DBS has developed into a promising approach to medically refractory movement disorders.[30,37,65] With improved understanding of sensorimotor pathways and psychiatric illness, the indications for DBS have grown. However, as the indications grow, so does the patient population at risk for unfavorable DBS outcomes. The very nature of DBS demands absolute precision with respect to electrode placement. Any operative or perioperative event that could negatively influence electrode positioning imparts a morbidity risk and therefore becomes a potential target for checklist interception. Such events include errors in frame placement, imprecise MRI targeting, improper bur hole location, inaccurate signal recording and electrode implantation, and careless closing. A successful checklist must incorporate boxes for each of these steps if DBS morbidity is to be minimized.

In 2009, Connolly et al.[13] described the first checklist specifically designed for DBS, which carefully addressed these steps in detail. In 2012, the same group published

TABLE 1: Summary of and outcomes for surgical checklists in various medical and surgical fields*

Authors & Year	Specialty	Aims	Outcomes
Robb et al., 2012	GI surgery	assess performance of laparoscopic cholecystectomies	decreased conversion to open cholecystectomy in females & pts w/ Grade III & IV gallbladder disease
de Vries et al., 2012	general surgery	assess no., nature, & timing of incidents intercepted by use of the SURPASS	≥1 incidents were intercepted in 2563 checklists (40.6%), w/ majority of incidents intercepted in preop & postop stages
Berrisford et al., 2012	cardiothoracic surgery	audit errors captured by an extended surgical time-out checklist	VTE prophylaxis, blood products, & clerical & imaging errors were captured, in addition to reduction in VTE prophylaxis errors after checklist
Calland et al., 2011	GI surgery	assess improvement in teamwork, situation awareness, & error catching	no difference in pt outcomes, case time, or proficiency; less satisfactory subjective comfort, team efficiency, & communication
de Vries et al., 2011	general surgery	assess prevention of malpractice claims using a surgical safety checklist (SURPASS)	29% of malpractice claims may have been intercepted by SURPASS checklist; may have prevented 40% of deaths & 29% of permanent damage
Nilsson et al., 2010	anesthesiology	assess personnel attitudes toward preop time-out checklist	93% noted contribution to increased pt safety; 86% noted opportunity to identify & solve problems; factors considered important by 78–84% were pt identity, correct procedure, correct side, allergy checking, contagious disease
Peyré et al., 2010	general surgery	determine reliability of laparoscopic Nissen fundoplication procedural checklist as a measurement of advanced technical skill	higher degree of surgical reliability w/ Nissen procedural checklist
Buzink et al., 2010	surgical endoscopy	investigate digital checklists in the no. & type of equipment- & instrument-related RSEs during laparoscopic cholecystectomies	at least 1 RSE initially identified in 87% of procedures; digital checklist reduced RSEs to 47%; overall reduction in no. of RSEs by 65%
de Vries et al., 2010[16]	general surgery	determine effect of SURPASS checklist on timing of antibiotic prophylaxis	increased interval btwn administration of antibiotic prophylaxis & incision ranged from 23.9 min to 29.9 min (32.9 min in procedures in which the checklist was used); significant decrease in no. of pts who did not receive antibiotics until incision
Semel et al., 2010	multiple surgical specialities	decision analysis comparing implementation of WHO surgical safety checklist to existing practice in US hospitals	in hospitals w/ baseline complication rates of at least 3%, implementation generated cost savings after prevention of at least 5 major complications
Chua et al., 2010	trauma surgery	determine adherence to infection protocols & impact on infection & complications	cases of central line infections, urinary tract infections, & ventilator-associated pneumonia decreased by 100%, 26%, & 82%, respectively, during study period
Peyre et al., 2009	surgical endoscopy	develop a procedural checklist for laparoscopic Nissen fundoplication	65-step procedural checklist created; subjective improvement in learning model for resident education
de Vries et al., 2009	general surgery	develop SURPASS checklist	in 171 high-risk procedures, 593 process deviations observed; 96% corresponded to a checklist item
Byrnes et al., 2009	critical care	assess effect of checklist on consideration of ICU protocols	verbal consideration improved from 90.9% to 99.7% in the following: DVT prophylaxis, stress ulcer prophylaxis, oral care for pts undergoing ventilation, electrolyte repletion, initiation of physical therapy, & documentation of restraint orders; increased pt transfer out of ICU on telemetry & initiation of physical therapy
DuBose et al., 2008	trauma surgery	examine effectiveness of Quality Rounds Checklist (QRC) tool to increase prophylaxis	improvement in 16 measures w/ <95% compliance initially identified
Lingard et al., 2008	anesthesiology	assess whether structured briefings improve OR communication	mean no. of failures per procedure declined from 3.95 to 1.31; 34% of briefings identified problems, resolved critical knowledge gaps, & resulted in follow-up actions

(continued)

TABLE 1: Summary of and outcomes for surgical checklists in various medical and surgical fields* *(continued)*

Authors & Year	Specialty	Aims	Outcomes
Verdaasdonk et al., 2008	surgical endoscopy	determine reduction in no. of incidents w/ technical laparoscopic equipment	53% reduction in total no. of incidents vs control; overall reduction in problems w/ laparoscopic equipment
Clark et al., 2007	obstetrics & gynecology	examine effects of checklist-based protocol for oxytocin administration on maternal & fetal outcome	improvement in indices of newborn outcome; system-wide decline in rate of cesarean section deliveries (from 23.6% to 21%) in 1-yr period
Lingard et al., 2006	anesthesiology	assess feasibility of checklist use in OR & perceived functions of the checklist discussion	respondents saw subjective value in checklist discussion; however, it impeded work flow patterns
Romagnuolo et al., 2005	gastroenterology & hepatology	examine effect of improved communication on hospital stay for upper GI bleeding	checklist reduced in-patient stay from median 7 days to 3.5 days
Hart & Owen, 2005	anesthesiology	create checklist to improve general endotracheal anesthesia for cesarean section delivery	95% of respondents assessed checklist as useful; 80% support use in simulations
Soyer et al., 2004	dermatology	evaluate diagnostic performance of nonexperts by using a 3-point checklist based on a simplified dermoscopic pattern analysis	improvement in diagnosis of melanoma in nonexperts compared to experts

* DVT = deep vein thrombosis; GI = gastrointestinal; pt = patient; RSE = risk-sensitive event; VTE = venous thromboembolism.

their results in 28 patients treated for either Parkinson disease or essential tremor.[39] The first series of 17 patients underwent DBS without the use of a checklist, whereas the remaining 11 were treated following checklist implementation. In this relatively small study, the use of a checklist decreased the incidence of major errors more than 3-fold; from 11 to 3. A similar trend was seen regarding minor errors, and among the 5 cases without a single detected error, each used the checklist protocol. Although small in scope, this investigation emphasizes the importance of a systematic and detailed means by which to identify and minimize preventable errors. Indeed, further studies are necessary to validate this tool, but in the meantime Kramer and coauthors have provided a benchmark for the functional neurosurgeon. We summarize their findings in Table 4.

Vascular Neurosurgery. This type of neurosurgery has perhaps the greatest potential for preventing devastating complications. Often involving critically ill patients in emergency situations, whether the procedure involves an endovascular technique or open microsurgery, checklists can vastly improve safety in this high-risk patient population.

With respect to endovascular procedures, Lawson et al.[41] found that the most common complication involved the vascular access site (5%), a relatively benign complication. Dawkins et al.[15] found the following rates of complications in 2924 diagnostic angiograms: 0.41% significant puncture-site hematomas, 0.34% transient neurological events, and 1 nonfatal reaction to contrast agent. There were no permanent neurological complications. However, endovascular interventions for treatment, such as coil placement or stent insertion, pose much greater risks, including aneurysm rupture, arterial dissection, hemorrhage, thromboembolism, and microembolism.[41] Vascular surgeries requiring craniotomy, such as aneurysm clipping, carry the most risk in this subspecialty. Bulters et al.[6] analyzed 200 patients who underwent surgical clipping and found a 19% complication rate, including direct brain injury, cranial nerve injury, postoperative hematoma, and ischemic events.

The current literature contains 2 types of vascular checklists: 1) a routine checklist for all cases, and 2) a checklist in case of emergency. Fargen et al.[27] proposed an endovascular checklist to be completed prior to all endovascular interventions, as summarized in Table 5.[27] Conversely, in emergency situations, Taussky et al.[57] postulated a checklist in case of aneurysm perforation during coil placement, seen in Table 6. Similarly, Chen[10] formed 2 checklists in the following cases: 1) aneurysm rupture, with overall goals of hemostasis and ICP management; and 2) thromboembolic events, with overall goals of thrombolysis and distal perfusion optimization, as summarized in Table 7. Interestingly, Chen divided his checklists into individual OR personnel roles, rather than team responsibilities, suggesting an alternate manner to delegate responsibility.

Spine Surgery. Rates of spine surgery have increased steadily in recent years, and the US currently has the highest rate of spine surgery in the world.[22,23] As the use

TABLE 2: Summary of and outcomes for validated neurosurgery operative checklists*

Authors & Year	Specialty	Aims	Outcomes
Fargen et al., 2012	vascular	standardize unique demands of neurointerventional procedures	after checklist implementation, total no. of adverse events was reduced by 35%, & 95% of staff championed checklist continuation
Kramer et al., 2012	stereotactic & functional neurosurgery	assess improvement in no. of errors w/ long-term checklist use	reduction in no. of errors after 1 yr of use, from 3.2 to 0.8 total errors per case
Da Silva-Freitas et al., 2012	general neurosurgery	evaluate a modified WHO surgical safety checklist on the safety & quality of care of neurosurgical pts	identification of 51 events in 44 ops; correction of 88% of errors prior to initiation of surgery
Matsumae et al., 2011	general neurosurgery	evaluate effect on surgical quality & communication	NA
Chen, 2011	vascular	design endovascular checklists in the event of aneurysm perforation & thromboembolic event	NA
Lyons, 2010	general neurosurgery	prevent rare errors, ensure correct imaging studies, & ensure antibiotic prophylaxis	no wrong-site, wrong-procedure, or wrong-patient error in 8 yrs of study; initiation of safety culture
Taussky et al., 2010	vascular	design endovascular checklist in event of aneurysm perforation during coil insertion	NA
Connolly et al., 2009	stereotactic & functional neurosurgery	detect & remediate procedural errors	no change in no. of errors; decreased time to complete checklist
NASS, 2001	spine	prevent wrong-site, wrong-level surgery	NA

* NA = not assessed.

of spine surgery and instrumented fusion increases, so do complication rates. Potential complications encountered during spine surgery are vast, and can occur during the intraoperative and postoperative period. This morbidity includes durotomy, pseudomeningocele, transient neurological deficit, and permanent neurological deficit, in addition to long-term complications such as pseudarthroses, adjacent-segment disease, and hardware failure. However, one of the most preventable complications in spine surgery is wrong-level surgery.[21] Wrong-level surgery is defined as a surgical procedure performed at the correct site but at the wrong level of the operative field; for example, performing a laminectomy on an unintended intervertebral level adjacent to an intervertebral level with an identified pathological entity. Ammerman et al.[2] reported that without intraoperative radiographs, surgeons initially exposed the wrong level 15% of the time in a prospective study of 100 discectomies. A 2010 study stated that wrong-level surgery at the L5–S1 region was the most common, with wrong-level surgery occurring in an average of 6.8 discectomies for every 10,000 procedures performed.[21]

TABLE 3: General neurosurgical operative site checklist developed by Lyons

Physician: ____________________
Procedure: ____________________
Date: __________
□ Confirmed identity of the patient
□ Confirmed medical record is for the correct patient
□ Confirmed x-rays are for the correct patient
□ Confirmed the correct op
□ Confirmed that consent form is signed for the correct op
□ Antibiotic given as ordered
Signature of surgeon completing the checklist: __________

In 2001, the NASS developed the "Sign, Mark and X-ray" program. This program consists of a checklist seeking to improve patient safety and decrease complications during spine operations, as seen in Table 8.[47] However, evidence suggests that the NASS checklist is insufficient to minimize wrong-level surgery. Later this was ratified into the "Universal Protocol for Preventing Wrong Site, Wrong Procedure, Wrong Person Injury," which has since been mandated for all accredited hospitals.[36] The NASS checklist is more than a decade old, and to reduce wrong-level surgery, this checklist should be augmented with intraoperative imaging after exposure and marking of a fixed anatomical structure.[21] Currently, spine surgery lacks a comprehensive perioperative checklist whose implementation has been able to demonstrate a reduction in wrong-level surgery.

Tumor and Pediatrics. Oncology and pediatric neurosurgery represent 2 of the most understudied areas in the checklist literature. Tumor surgery, especially lesions involving the skull base, presents a challenge to even the most experienced surgeons. Recent reports have shown complication rates of skull base surgery to be as high as 48.6%.[24] In a study of 30 patients undergoing skull base tumor resection, Sakashita et al.[52] identified a complication in 40% of cases, and found that those with prior chemotherapy or radiation and dural resection had higher complication rates. No checklist aiming to prevent errors

TABLE 4: Functional neurosurgery OR checklist developed by Kramer et al.*

I. Frame placement
☐ Complete pin set
☐ Frame bolts tight
☐ Localizer purged
☐ Nose & occiput clear
☐ Head inspected for previous lead, shunt, or craniotomy
☐ Local anesthetic injected
OK to place pins
☐ Pins tight
☐ Frame center rechecked
☐ Frame tools & local anesthetic on cart OK to travel
OK to travel
II. Targeting & positioning
MRI
☐ Frame x-translation <3 mm; actual value ____________
☐ Roll, yaw, pitch acceptable
OR
☐ Lt target systematic error = x + 1.5
☐ Rt target systematic error = x – 1
☐ Mayfield adaptor & headrest tight
☐ Pin sites reinjected
OK to scrub
III. Incision & bur hole
☐ Fluoroscopy time to center = ____________
☐ Inject local anesthetic
☐ Recheck coordinates & verify transcription to field
☐ Bur location “makes sense”
☐ Reminder to change x for contralat (check when called)
☐ Reverify side if unilat
☐ x-relaxation
OK to start
☐ Cannula true
☐ z-offset 25
☐ Microelectrode correct length
IV. Recording & implantation
☐ Read declination & azimuth
☐ Run simulation
☐ Zero motor
☐ Setscrews tight
☐ SBP <140 mm Hg
OK to cannulate
☐ Macroelectrode correct length
☐ Electrode adapter attached
OK to implant
☐ For bilat case, change x-coordinate & repeat sublist “R&I” (check when called)
☐ Reverify generator implantation site(s)
☐ Sponge count correct

(continued)

TABLE 4: Functional neurosurgery OR checklist developed by Kramer et al.* ***(continued)***

OK to close
V. Part B before closing
☐ Lead-to-extension setscrews tight
☐ Lt boot white/rt boot clear
☐ Identify lt & rt for generator
☐ Skip incision closed
☐ Check for buttonhole
OK to close

* R&I = recording and implantation; SBP = systolic blood pressure.

specific to brain tumor resection or biopsy currently exists. However, Arriaga et al.[3] created a clinical pathway for acoustic neuroma management, specifically mandating ICU bed days aimed at cutting costs. Additionally, Kraus et al.[40] published a standardized regimen of antibiotics to prevent infectious complications after skull base surgery, and found a significant reduction when using a regimen consisting of ceftazidime, flagyl, and vancomycin. Neither project addressed intraoperative checklists.[3,40]

Complications in pediatric neurosurgery can cause significant morbidity and lead to repeat surgical intervention. Operating on newborns involves challenges unique to pediatrics.[1] Drake et al.[25] evaluated 1082 pediatric neurosurgical procedures and noted a 16.4% complication rate, with the most common complications occurring in vascular surgery (41.7%) and brain tumor surgery (27.9%). The most common complications were CSF leakage, new neurological deficit, early shunt or endoscopic ventriculostomy obstruction, and shunt infection.

In a thorough review of the oncology and pediatric neurosurgical literature, no perioperative checklists were found. This represents an active area of research, in which standardized protocols are needed.

Discussion

The field of neurosurgery is at an exciting point with respect to quality improvement and surgical checklists. The majority of checklists have evolved in the last 4 years. If this trend continues, an exponential growth in operative checklists is expected, aimed at standardizing procedures and maximizing patient safety. After reviewing the literature, several themes arose.

The term “checklist” defines several different entities. First, there are general surgical checklists applicable to all procedures, aimed at confirming the most vital identifying information—correct patient, procedure, and surgical site.[15,44–46] These measures target the most salient aspects of any surgical case without standardizing specifics of an operation. Nearly all surgical subspecialties, including neurosurgery, gained experience with generic checklists after the Joint Commission mandated a standardized time-out. Second, there are checklists aimed at the successful completion of a specific type of operation.[30,39] Third, in the case of unexpected intraoperative emergencies, checklists exist to standardize the un-

TABLE 5: Endovascular neurosurgery safety checklist developed by Fargen et al.

I. Before induction of anesthesia
Patient has confirmed:
□ Identity
□ Procedure
□ Consent
□ Yes □ No Does the patient need an arterial line or anesthesia?
□ Yes □ No Known allergy to contrast or anesthetic?
□ Yes □ No Difficult airway/aspiration risk?
□ Yes □ No Patient radiation level/planned radiation exposure discussed
□ Yes □ No Any chance patient may be pregnant? (Perform pregnancy test if yes)
Radiation technologist confirms correct patient information logged in computer
II. Before obtaining access
□ Confirm that all team members have introduced themselves by name & role
□ Proceduralist & anesthesia team member confirm patient & procedure
Proceduralist confirms:
□ Sheath size
□ Initial catheter & wire
□ No. of pressure bags
□ Planned instruments & procedure
□ Access/tortuosity concerns
□ Pulses in ankle/wrist palpated & results documented
Patient wt ___________ kg
Maximum contrast dose (for given wt): ___________ ml
□ Yes □ No Patient creatinine available? If yes, ___________ mg/dl
□ Yes □ No Heparin needed? If yes, starting dose: ___________ units
□ Yes □ No Is patient on blood thinners? If yes, ___________
III. Before patient leaves interventional radiology suite
□ Proceduralist confirms arteriotomy closure
□ Team confirms amount of contrast given: ___________ ml
□ Proceduralist confirms pulses in ankle/wrist palpated & results documented
□ Yes □ No Any equipment problems that need to be addressed?
□ Team confirms who will discuss procedural results w/ primary team & patient &/or family

planned.[10,64] All 3 brands of checklists fill a niche within neurosurgery.

Checklist organization also varies. Whereas Taussky et al. identified general team duties in case of aneurysm rupture, Chen et al. divided team responsibilities into individual roles—proceduralist, anesthesia, nursing, and technician. No data exist as to which model is more efficacious. Similarly, Lyons et al. published the only checklist that required a direct surgeon signature. Most checklist measures are implemented by nursing staff or by anyone on the operative team.

But is the mechanistic approach of simply completing a checklist enough? Creating a culture of safety and recognizing hierarchical communication constraints are paramount to successful checklist implementation. The field of aviation is replete with research on communication in high-pressure situations. The work of Sexton and Helmreich[54] on cockpit linguistics showed that the way in which crew members verbally interact with one another impacted performance and error rates. Increased words and use of the first person plural (we, our, us) were linked to increased performance and communication, and de-

TABLE 6: Vascular complications in neurosurgery Checklist 1 developed by Taussky et al.*

Aneurysm perforation checklist
Identification of perforation
□ Wire/coil beyond aneurysm edge
□ Alert anesthesia about perforation
□ Do not retract wire/catheter/coil
□ Perform angiography to look for extravasation
□ Look at transit time
□ Consider CT now/after
Clinical examination
□ Pupil status
□ Glasgow Coma Scale score
□ BP change
□ Focal neurological deficit
□ Agitation
Medical management
□ BP modulation
□ Administer protamine if patient is on anticoagulation therapy
□ Consider mannitol
□ Consider pentobarbital
Endovascular management
□ Consider second microcatheter
□ Consider balloon inflation
□ Continue w/ packing of aneurysm
Closing up
□ Inform ICU
□ Inform neurosurgery
□ Consider EVD/craniotomy

* BP = blood pressure; EVD = external ventricular drain.

creased error rates. Additionally, the language used in the preceding flight impacted subsequent flights. Helmreich and Musson[34] also defined the following behaviors as ones that help prevent error and support teamwork: monitoring and challenging other team members, defining leadership responsibilities, sharing mental models, and briefing and debriefing.

In another paper examining the effects of crew resource management, Helmreich[33] observed that the greatest value of communication is in discovering hidden threats that can lead to error. Thomas et al.[58] polled ICU physicians and nurses and asked them to rate collaboration and communication with each other. Physicians rated 73% of nurses favorably and 70% of physicians favorably, whereas nurses rated 71% of nurses favorably, but only 33% of physicians favorably. From the nursing perspective, much improvement in communication and teamwork was needed between nurses and doctors. In the OR, researchers have studied communication and have defined the interface between surgeon and anesthesiologist as one of client and service provider, rather than as a cohesive team.[33,34] The more appropriate conceptualization of an OR is of a single team in which the surgeon is not the captain, and all team members—anesthesiologist, sur-

TABLE 7: Vascular complications in neurosurgery Checklist 2 developed by Chen*

I. Aneurysm perforation checklist
Neurointerventionalist
□ Reverse antithrombotics (protamine)
□ Complete aneurysm embolization
□ Monitor ICP
Monitor transit time
Hemodynamics
Ventriculostomy
□ Disposition—EVD or hematoma evacuation
Anesthesiology
□ Page attending physician
□ Secure airway & ventilate w/ 100% O_2
□ Antithrombotic reversal at neurointerventionalist's direction
Protamine bolus 10 mg per 1000 U heparin
Monitor for cardiopulmonary reaction
Aspirin/clopidogrel reversal, 5 single units of platelets & 0.3 mg/kg iv bolus of desmopressin
□ SBP <120 mm Hg w/ iv nicardipine
□ ICP control
Hyperventilate
Mannitol 0.5 g/kg, rapid infusion
Neuroprotection
Passive cooling to 33°C–34°C
Nursing
□ Observe CSF color change
□ Monitor hemodynamic changes for Cushing reflex
□ Prepare EVD
□ Page neurosurgery resident if necessary
□ Prepare medications
Mannitol
Protamine
Nicardipine
Anticonvulsant
Technologist
□ Assist w/ hemostasis
□ Prepare to open compliant balloons or *N*-butyl cyanoacrylate
□ Prepare for possible DynaCT
□ Call CT about possible emergency scan
II. Thromboembolic complication checklist
Neurointerventionalist
□ Determine clinical significance of lesion
Check for neuromonitoring changes
Evaluate collateral angiographic flow
□ Check guide catheter for flow-limiting vasospasm
□ Complete embolization of ruptured aneurysm
□ Superselective intraarterial abciximab 2-mg boluses up to 10 mg
□ Prepare to use aspiration devices

(continued)

TABLE 7: Vascular complications in neurosurgery Checklist 2 developed by Chen* *(continued)*

Neurointerventionalist *(continued)*
□ End point
Angiographic recanalization
Maximum abciximab
Neuromonitoring changes or improved collateral vessels
Anesthesiology
□ Hypervolemia, use normal saline
□ Optimize collateral cerebral perfusion
Nursing
□ Anticoagulation (give heparin if activated clotting time <250 sec)
□ Antiplatelets (abciximab intraarterially, 2-mg boluses up to 10 mg)
□ Vasospasm (verapamil or nicardipine)
Technologist
□ Thrombolysis
Prepare stroke aspiration devices
Record complication onset time
Observe for angiographic changes

* iv = intravenous.

geon, nurses, support staff—feel empowered to speak if a safety issue arises.[33] Overall, successful checklist implementation is more than checking boxes. A culture of open communication and an egalitarian relationship between all surgical team members are required. Under this model, hierarchical rivalries become subordinate to achieving patient safety as the highest end point.

Conclusions

The neurosurgical literature on checklists is limited, yet currently evolving. By reviewing current neurosurgical peer-reviewed checklists, it is our aim to educate our colleagues on how leaders in this area have standardized patient safety measures, with the end goal being the design of successful quality measures to improve patient safety.

Disclosure

Dr. Mocco is a consultant for the following companies: Lazarus Effect, Inc.; NFocus; and Edge Therapeutics. He has direct stock ownership in Blockade Therapeutics.

Author contributions to the study and manuscript preparation include the following. Conception and design: Mocco. Drafting the article: Zuckerman, Green, Carr, Dewan, Morone. Critically revising the article: Mocco, Zuckerman, Carr, Dewan, Morone. Reviewed submitted version of manuscript: Mocco, Zuckerman, Green. Approved the final version of the manuscript on behalf of all authors: Mocco. Study supervision: Mocco.

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TABLE 8: Spine surgery wrong-level checklist developed by NASS*

□ Involve patient in confirming the operative site either through informed consent or during the actual marking. Surgeons are encouraged to obtain informed consent personally. Copies of the operative permit/informed consent form should state the site & side of surgery & be shared w/ patient, surgeon, anesthesiologist, assistant or scrub nurse, & circulating nurse.
□ Sign your name to the operative site.
□ Each member of the operative team should verify the correct site.
□ Verify that x-rays & medical records are for the correct patient, as well as confirming identity of the patient.
Each of the following items should be double-checked against the marked site:
□ Medical records
□ x-rays & other imaging studies (marked "L" or "R" to prevent being placed backward on the light box)
□ Informed consent
□ OR/anesthesia record
□ Consider having your assistant or scrub nurse always stand opposite the side where the surgeon should stand.
□ Consider or suggest an intraoperative x-ray during surgery, after exposure using markers that do not move to confirm the vertebral level to be operated. Consider a radiology reading.

* The "Sign, Mark & X-ray (SMaX)" checklist; see reference 46.

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