ScientificScholar®
Knowledge is power
Publisher of Scientific Journals

www.surgicalneurologyint.com

Surgical Neurology International

Editor-in-Chief: Nancy E. Epstein, MD, Professor of Clinical Neurosurgery, School of Medicine, State U. of NY at Stony Brook.

SNI: Spine

Editor
Nancy E. Epstein, MD
Professor of Clinical Neurosurgery, School of Medicine, State U. of NY at Stony Brook

SNI
Open Access

Review Article

Anterior cervical surgery for morbidly obese patients should be performed in-hospitals

Nancy E. Epstein[1], Marc A. Agulnick[2]

[1]Professor of Clinical Neurosurgery, School of Medicine, State University of NY at Stony Brook and Editor-in-Chief Surgical Neurology International NY, USA, and c/o Dr. Marc Agulnick, 1122 Franklin Avenue Suite 106, Garden City, NY, USA, [2]Assistant Clinical Professor of Orthopedics, NYU Langone Hospital, Long Island, NY, USA, 1122 Frankling Avenue Suite 106, Garden City, NY, USA.

E-mail: *Nancy E Epstein - nancy.epsteinmd@gmail.com; Marc A. Agulnick - marc_agulnick@yahoo.com

***Corresponding author:**
Nancy E Epstein, M.D., F.A.C.S.,
Professor of Clinical Neurosurgery, School of Medicine, State University of NY at Stony Brook, and Editor-in-Chief of Surgical Neurology International NY, USA, and c/o Dr. Marc Agulnick, 1122 Franklin Avenue Suite 106, Garden City, NY, USA.

nancy.epsteinmd@gmail.com

Received: 29 November 2023
Accepted: 30 November 2023
Published: 05 January 2024

DOI
10.25259/SNI_957_2023

Quick Response Code:

ABSTRACT

Background: Morbid obesity (MO) is defined by the World Health Organization (WHO) as Class II (i.e. Body Mass Index (BMI) >/= 35 kg/M2 + 2 comorbidities) or Class III (i.e. BMI >/= 40 kg/M2). Here, we reviewed the rates for adverse event/s (AE)/morbidity/mortality for MO patients undergoing anterior cervical surgery as inpatients/in-hospitals, and asked whether this should be considered the standard of care?

Methods: We reviewed multiple studies to document the AE/morbidity/mortality rates for performing anterior cervical surgery (i.e., largely ACDF) for MO patients as inpatients/in-hospitals.

Results: MO patients undergoing anterior cervical surgery may develop perioperative/postoperative AE, including postoperative epidural hematomas (PEH), that can lead to acute/delayed cardiorespiratory arrests. MO patients in-hospitals have 24/7 availability of anesthesiologists (i.e. to intubate/run codes) and surgeons (i.e. to evacuate anterior acute hematomas) who can best handle typically witnessed cardiorespiratory arrests. Alternatively, after average 4-7.5 hr. postoperative care unit (PACU) observation, Ambulatory Surgical Center (ASC) patients are sent to unmonitored floors for the remainder of their 23-hour stays, while those in Outpatient SurgiCenters (OSC) are discharged home. Either for ASC or OSC patients, cardiorespiratory arrests are usually unwitnessed, and, therefore, are more likely to lead to greater morbidity/mortality.

Conclusion: Anterior cervical surgery for MO patients is best/most safely performed as inpatients/in-hospitals where significant postoperative AE, including cardiorespiratory arrests, are most likely to be witnessed events, and appropriately emergently treated with better outcomes. Alternatively, MO patients undergoing anterior cervical procedures in ASC/OSC will more probably have unwitnessed AE/cardiorespiratory arrests, resulting in poorer outcomes with higher mortality rates. Given these findings, isn't it safest for MO patients to undergo anterior cervical surgery as inpatients/in-hospitals, and shouldn't this be considered the standard of care?

KEY WORDS: Anterior Cervical Surgery, Postoperative Epidural Hematomas (PEH), Risks, Adverse Events, Patient Selection, Morbid Obesity (MO), Contraindication Outpatient Surgery, Morbidity/Mortality, Cardiorespiratory Arrests, Witnessed, Unwitnessed

INTRODUCTION

Morbid obesity is defined as Class II (i.e. Body Mass Index >/= 35 kg/M2 + 2 comorbidities) and Class III (i.e. BMI >/= 40) by the World Health Organization (WHO) [Table 1]. Specifically for MO patients undergoing anterior cervical surgery (i.e. mostly anterior cervical discectomy/fusion (ACDF), some anterior corpectomy/fusions (ACF), and cervical disc

Table 1: Summary of Data.

Author [Ref] Journal Year	Study Design	Results	Results	Results	Outcomes
Hans[7] **J Neurosurg Anesthesiol 2003**	Case Report Acute SEH-C67 Disc	2.5 Postop Hrs Respiratory Distress Flaccid Quad	Immediate Return to OR without MR Not Successful	MR after 2nd OR- Posterior PH C3-T3 No Sig. Cord Compression	C Lam Removed PH 5 D D/C No N-No Coag Disorder
Garringer[5] **J Spinal Disord Tech 2010**	Safety Anterior CSS Done in ASC Retro Evaluation 645 Cases-Comp <48 Hrs Postop	Acute Comp Unplanned Readmit 1-Level Disc/stenosis	2 (0.3%) Acute Comp SEH-C No RPH No Mort Within 4 Postop Hrs (PACU Obs) Fully Resolved-ND	6 Unplanned Readmit (80% Pain/Nausea) 2 (0;3%) SEH-C Level ACDF Safely Performed in ASC with 4 hr PACU obs	Lower Readmit Rate by 1/3 if Avoid Iliac Autograft Also Questioned: Use Postop Drains?
Williams[23] **Spine 2011**	Does BMP Increase Periop AE 55,862 Spine Fusions +/- BMP-Used BMP 21% or 11,933 Cases	Excluding CSS Same AE +/- BMP BMP with CSS-More Overall AE 5.8% + BMP vs. 2.4% No BMP	CSS with BPM More Fusion Inf 2.1% vs. 0.4% no BMP	Anterior CSS Fusions BMP Sig > AE (New or Revision Surgery)	BMP with Anterior CSS Increased Rate AE Not True for Posterior CSS or TL Fusions
Kalanithi[10] **Spine 2012**	MO Increased Cost and AE with All Spine Fusions in California 2003-7 84,607 Admits 1455 MO	Used CA-SID 4 Fusion Anterior CF, Posterior CF, ALIF, PLIF	Comorbid Outcomes AE In-Hospitals Secondary Cost, LOS, Mort In-Hospitals	MO 97% Higher In-hospital AE (13.6% vs. 6.9%) (Cardiac, Renal, Pulmonary, Wound)	MO Slight Higher Mort, LOS, Average Costs-Less Pronounced Posterior CF MO Most Sig. Predict AE + Anterior Cervical and PLIF
Protzman[18] **J Neurosurg Spine 2016**	T-SDH Rare After CSS 53yo F Paraparesis Hrs After ACDF C56	Return to OR for ACDF Removal Anterior SEH-C	Postop MR T SDH 3rd Surgery Lam	Postop Resolved ND with PT	Postop Spinal SDH Rare After ACDF Diagnosis Early Rx
Chotai[1] **Spine J 2016**	Premise: Obese pts > Comorbidity > AE, > Costs, Lower QALY After SS vs. Nonobese Pts Study Cost Utility and QALY Outcome ACDF Obese Pts	Studied: 1-2 Year Medical Resource Use, Missed Work, QALY Obese BMI > 35) Class II MO BMI >/= 40 Class III	Significant Imp Pain QALY (NDI, SF 12, Euro Quol -5D) 2 Yr No Sig. Diff-Post-Discharge Data 1-2 Yr	Mean 2 Yr Direct Cost Obese Pt $19, 225 vs. $17,635 Non Obese No Sig Diff Mean Total 2 Yr Cost Obese $223, 144 vs. Non Obese $22,183	MO Pt Lower Cost Effective- Sig Imp Outcomes MO Lower QALY Gained + Higher Cost/QALY Gained $138,094 at 2 Yrs
Epstein[2] **Surg Neurol Int 2017**	Bariatric Bypass (BS) Contributes to Loss BMD -Lessens Axial Back Pain - MO Pts	Many Spine Surgeons Rec Wt Loss Prior to SS	MO BMI +/= 35 Kg/M2 + 2 Comorbid WHO Class II MO BMI +/= 40 WHO Class III	In 2 Postop Yrs of BS-Wt Reduced Less Axial LBP, Also >Vit D Deficiency + > Loss BMD	> Fx MO Pts May Have BS Surgery-Sig Wt Reduction Also < Vit D Levels, < BMD, > Fx Risk
Epstein[3] **Surg Neurol Int 2017**	Most Studies Show More Risks AE Elective SS in MO Pts	MO: BMI =/> 35 kg/M2+ 2 (Class II) Comorbid Factors MO BMI =/> 40 kg/M2 (Class III)	Higher OR Risks < Quality MR/CT Wrong Level OR Poor X-rays	Higher Risk Periop AE DVT, PE, Pn, CAD, Blindness, Plexus Injuries, Anesthesia, SEH, Seroma	Most Literature Showed >> Risk MO Patients SS Consider Major Preop Wt Loss/BS Optimized Outcome

(Contd...)

Table 1: *(Continued).*

Author [Ref] Journal Year	Study Design	Results	Results	Results	Outcomes
Schroeder[21] **Global Spine 2017**	SEH After CSS 2005-2011 23 Sites	16,582 CSS 15 SEH 0.09% 11 Sites No SEH	All Pts ND 9 Full Rec 2 of 3 with Delay Rx Residual ND	4 of 12 (33%) No Delay Rx Residual ND 15 SEH Pts No Imp	Rate SEH with CSS 1/1000 Rec; Prompt Diagnosis Early Rx
Martin[14] **Iowa Orthop J 2018**	Compare Costs AE 30-Days for ACDF Inpatient vs. Outpatient 2007-2014 18,386 PearlDiver Database AE Lower 30-D Sig Less	Outpatients Comorbid Discharge Stable < 20% Outpatients 39,528 vs 47,330 Payment Reduced 1/3 2008-2014	90-Day Cost Outpatient Lower 30-D AE 9.5% vs. Inpatient 18.6% Outpatients Sig Less Comorbid	Inpatients > Comorbid Older Age Obesity CAD Renal Pulmonary	"Appropriate Pt Selection is key, and the SOC nationally for the comorbid patient remains inpatient admission"
Miao[15] **Neurochirurgie 2018**	Rx PH After CSS:15 Cases	7 RPH-C (0.5%) 8 SEH-C (0.6%) MJOA Scores Same +/- PH	Paralysis at Presentation 1 Grade B 6 Grade C 8 Grade D	Risk Factors for PH OPLL Long OR More Levels Higher BMI	Summary PH C Risk Factors OPLL Multilevel Higher BMI Longer OR
Kapadia[11] **Clin Spine Surg 2019**	Risk Factors DT/ CSF Leaks ACDF NIS 1998-2010 Excluded OPLL	1,261,140 Pts 3048 (0.24%) Postop CSF Leak Ages 55-69 or > 70 Greater Risk DT	Factors >Risk DT Non-White Obesity HTN No > Risk DT: DM HLip	HNP < Risk CSM > Risk >LOS DT 6.0 Days vs. 2.1 Controls Higher Risk DT: Older Non-White, > Obese HTN	"Patients Benefit from Medical OptimizationPreop"
Yerneni[24] **Neurosurgery 2020**	Safety ACDF Outpatient Reviews Before April 2018 -21 Articles-Most Retrospective Lack Level I or II Evidence	No Sig Difference Inpatient vs. Outpatient ACDF Risk AE, Stroke, DVT/PE, Dysphagia, Clot	Outpatient ACDF Lower Reop Rates < Mort < LOS Lack High-Level Evidence	ACDF Safe Low AE Well Selected Outpatients vs. Inpatient ACDF	> Risks ≥Age >Comorbid >Obesity Sig Myelop "Are likely not suitable for outpatient ACDF."
Qi[19] **Clin Spine Surg 2020**	Obesity Impact Outcomes Multilevel ACDF-CSM 156 Pts 2010-2016 Risk Factors Neck Length > BMI, Multilevel OR	Outcomes NDI JOA Scores AE Followed 3.9 Yrs NDI/JOA Sig Imp 46 (24.49%) AE Postop	Risk Postop Dysphagia Multilevel ACDF Obese > AE Neck Length	Neutral Position BMI # of Levels > Postop AE Higher BMI	Larger Neck Shorter Neck > Duration Surgery > More EBL
Epstein[4] **Surg Neurol Int 2020**	Freq +Rx PH After ACDF ACF ACSS 0.4%-1.2% ACS-11 Studies	44, 030 Pts 4 Case St 2 Small Series 4 Large Series + NSQUIP Database	Risk Factors Cervical PH DISH, OPLL, OR Times > 4 hrs, Heparin, Multilevel Surgery, ASA Score =/> 3	Risk Factors Prone Smoking High or Low BMI Anemia Age > 65 MO, M	Drains Did NOT Prevent PH + Not Increase Inf or Reop R Early Diagnosis PH + Rx Critical Outcomes Limit Mor/Mort

(Contd...)

Table 1: *(Continued).*

Author [Ref] Journal Year	Study Design	Results	Results	Results	Outcomes
Ottesen[16] **Spine J 2020**	Both Under Wt and MO Pts Higher Risk Anterior CSS 2005-2016	NSQUIP Database 51,149 Anterior CSS-30-day AE, Readmit Postop Inf, Mort	ACDF, ACS, CA Normal Wt WHO) Normal Wt BMI 18.5-24.9 kg/M2	Under Wt-More Serious AE and Postop Inf MO More Minor AE	Anterior CSS with Both Under Wt and MO Greater AE
Koo[12] **World Neurosurg 2021**	Discharges ACDF CSM NIS +ICD 10 2016-2017 17, 385 Pts 3035 (17.4%) Obesity No Obesity 14,350	> Obese Pts 3 Or > Commorbid 43.5% vs. 28.1% No Obesity AE >Obesity 14.3% vs. 10.3% No Obesity	Higher Cost Obesity $1154 - 20,886 vs.None 19732	Obesity > Non Routine D/C 24.2% vs. 16.6% No Obesity	Non Routine D/C: >Obesity >Age, Race Coverage, Region, Comorbid, AE Rates
Malik[13] **Clin Spine Surg 2021**	Impact BS 90-D Postop Outcomes ACDF-PearlDiver 2007-13 Data 100% Medicare Standard Analytic Files (SAF 100)	Group 1 411 Pts Obese BMI >/= 35 kg/M2 with BS Surgery in 2 Yrs	Group 2 BMI >/= 35 kg/M2 No BS in 2 Yrs Of ACDF Surgery	Group I BS Before ACDF: < PE, <CAD <AE, <Sepsis, <Renal AE, <90-D Readmit	BS Surgery Wt Loss Prior to ACDF < 2 Yrs Reduced 90-day AE/Readmit Rates Should Tell BS Patients Benefits of BS Preop
Perez-Roman[17] **Neurospine 2021**	Study Preop AE Obesity on ACDF NIS 2004-2014	Used ICD10 Coding 1,212,475 ACDF	9.2% Obese (Rise from 5.8% to 13.4% Over Yrs)	Obese AE ACDF: >Dysphagia >New ND, >Resp AE,>Hemat AE, PE, DT	Obesity >Periop AE ACDF for Inpatients
Rogerson[20] **Orthopedics 2021**	ACDF Risks Factors Medical/ Surgical Inpatient AE 1-2 Level ACDF NIS 2006-2010 78,771 Pts	Inpatient Mortality 0.074% Overall AE 3.73% Risk Medical AE 3.13% Airway 0.75% ND 0.05%, SSI 0.04%	Risk Factors Chronic Kidney Disease Strongest Predictor Mort, Other Risks Resp AE, Age >65 Yrs, M, DM Myelop, Anemia/SSI	Other Risks Bleed Disorder COPD, Obesity, OSA > Preop Myelop> Postop ND	"Surgeons should consider these risk factors when deciding to perform ACDF surgery in an outpatient setting."
Hardman[8] **Clin Neurol Neurosurg 2022**	ACDF Respiratory Pulmonary Complications (RPC) 52,575 Admission ACDF 1454 RPC	NIS 2016-2018 All Elective ACDF	AE Abscess Angio-edema Laryngeal Edema Vocal Cord Paralysis Dysphonia Pneumonia Acute Resp Distress Syndrome	>AE/RPC with ACDF: Older Pts African American, Obese Pts DM, HTN Urban Local Multilevel	"Our study identified modifiable predictors of RPC after elective ACDF (e.g. **obesity,** diabetes) which can be used to guide preoperative patient optimization."
Joo[9] **Spine 2023**	Does Preop BS OR Alter AE Elective ACDF 2010-2020 PearlDiver Spine Database 160,166 Pts	Compare 3 Subcohorts (1)NonObeseControls No BS (2) 136 BS+MO-Last 2 Yrs BMI < 35 kg/M2	(3) 343 BMI > 35 mg/M2 BS + MO+ Last 2 Yrs, ACDF	90-Day AE Rates-Age Sex, ECI, LOS, KM Analysis 5 Yr CSS Reop Rates BS + MO- Not at Increased Risk AE	BS+MO+ Greater Risk 90-day PE, Wound Dehiscence Hematomas 5 Yr Reop Rates Same Rec: Wt Reduction Below MO Rg Preop

(Contd...)

Table 1: *(Continued).*

Author [Ref] Journal Year	Study Design	Results	Results	Results	Outcomes
Gross[6] **Word Neurosurg 2023**	MO Increased Duration ACDF Not Readmit or Reop Rates 670 1-level ACDF 2010-2022	413 (61.6%) Nonobese BMI < 30 226 (33.7%) Obese BMI 30-39.9 31(4.6%)MO BMI >/= 40	Factors Reviewed Time OR LOS BMI Linked Prior DVT, PE, DM	> BMI Increased Duration OR Not Reop or Readmit Rate, LOS or Time/ Local D/C	> BMI Increased Duration OR Not Reop Not Readmit Not LOS Same D/C
Subramanian[22] **Neurospine 2023**	Risk Factors Early Readmit + Non-Home D/CAfter CDR Rad 5,397 Pts Nonobese 3130 Class I 1348 Classes II/III 919	Impact Obesity 2005-2020 NSQUIP 1-2 Level CDR Morbidity AE < 30 D Postop, 30-D Readmit, AE, LOS, D/C	3 Cohorts Nonobese 3130 Pts BMI 18.5-29.9 kg/M2 Obese 1348 Class I BMI 30-34.9 kg/M2 MO Obese 919 Classes II/III BMI >/= 35 kg/M2	MO Class II/III More 2-level CDR More Non Home D/C 2.1% vs. 0.7% Obese vs. 0.5% Non Obese 0	More 30-day Readmit 2.1% MO vs 0.5% Non-Obese and 1.1% Obese MO No Sig Differences Reop Rate or Morbidity No Mortality

SNI=Surgical Neurology International, Rx=Treatment/Management PH=Postoperative Hematomas, ACDF=Anterior Cervical Diskectomy/Fusion, ACF=Anterior Corpectomy Fusion, ACSS=Anterior Cervical Spine Surgery, Postop=Postoperative, Pt(s)=Patient(s) NSQUIP= (National Surgical Quality Improvement Program, OPLL=Ossification Posterior Longitudinal Ligament, DISH= Diffuse Idiopathic Skeletal Hyperostosis, BMI=Body Mass Index, MC=Medical Comorbidities, M=Male, F=Female, Mor=Morbidity, Mort=Mortality, MO=Morbid Obesity, Freq=Frequency, SEH=Spinal Epidural Hematomas, RFH=Retropharyngeal Hematomas, WH=Wound Hematomas, Rg=Range, ACS=Anterior Cervical Surgery, St=Studies, OR=Operative/ Operating Room, ASA= American Society of Anesthesiologists, Hr=Hours, Yr(s)=Year, Wk=Week, D=Days. Reop=Reoperation, Inf=Infection, R=Rate, CSS=Cervical Spine Surgery, SEH=Spinal Epidural Hematoma, ND=Neurological Deficit, Rec=Recovery, Imp=Improvement, C=Cervical, T=Thoracic, L=Lumbar, Comp=Complications, Retro=Retrospective, Postop=Postoperative, PACU=Postoperative Care Unit, Obs=Observation., ASC=Ambulatory Surgical Center/Outpatient Center, Quad=Quadriplegia, Sig.=Significant, Lam=Laminectomy, Coag=Coagulation, SDH=Subdural Hematoma, PT=Physical Therapy, Periop=Perioperative, AE=Adverse Events, BMP=Bone Morphogenetic Protein, LOS=Length of Stay DVT=Deep Venous Thrombosis, PE=Pulmonary Embolism, DM-Diabetes, BS=Bariatric Surgery, ECI, Elixhauser Comorbidity Index, KM Analysis=Kaplan-Meier Analysis, Rec=Recommendation, SS=Spine Surgery, QALY=Quality-Adjusted Life Years, NDI=Neck Disability Index, SF-12=Short Form 12 CA=Cervical Arthroplasty, WHO=World Health Organization, CA-SID= Healthcare Cost and Utilization Project's California State Inpatient Databases, CF=Cervical Fusion, ALIF=Anterior Lumbar Interbody Fusion, PLIF=Posterior Lumbar Interbody Fusion, SNI=Surgical Neurology International, SS=Spine Surgery, BMD=Bone Mineral Density, LBP=Low Back Pain, Vit=Vitamin, Circ=Circumference, CSM=Cervical Spondylotic Myelopathy, NDI=Neck Disability Index (NDI), JOA=Japan Orthopedic Association Scores, EBL=Estimated Blood Loss, SAF 100=100% Medicare Standard Analytical Files, NIS=National Inpatient Sample, ICD=International Classification of Diseases, DT=Dural Tear, CDR=Cervical Disc Replacement, RPC=Respiratory Pulmonary Complications, Resp=Respiratory, HTN=Hypertension, ID=Identify, OSA=Obstructive Sleep Apnea, COPD=Chronic Obstructive Pulmonary Disease, CSF=Cerebrospinal Fluid, HLIp=Hyperlipidemia, HNP=Cervical Disc, SOC=Standard of Care, D/C=Discharged, Fx=Fracture, #=Number, Myelop=Myelopathy, Hemat=Hematology

arthroplasties (CDR)), we looked at the frequencies of postoperative adverse events (AE), including acute/delayed cardiorespiratory arrests, and the resultant morbidity and mortality rates for inpatients [Table 1]. We concluded, based on our review of MO patients undergoing anterior cervcial surgery as inpatients/in-hospitals, that this should be considered the standard of care.

1/1000 to 0.4-1.2% Incidence of Postoperative Spinal Epidural Hematomas (SEH) Following Anterior Cervical Surgery

Two studies looked at varying frequencies of postoperative SEH following anterior cervical surgery (i.e. 1/1000 to 0.4-1.2%) [Table 1].[15,21] Schroeder *et al.* (2017) looked at 16,582 cervical spine operations performed at 23 centers (2005-2011); for the 15 (i.e. 0.09% nearly 1/1000) postoperative spinal epidural hematomas (SEH), they recommended early diagnosis and treatment to optimize recoveries.[21] Miao *et al.* (2018) found 15 cases of postoperative hematomas following cervical spine surgery, citing seven retropharyngeal hematoms (RPH in 0.5%), and eight postoperative spinal epidural hematomas (SEH in 0.6%).[15] Patients with higher BMI and/or MO, those with OPLL (ossification of the posterior longitudinal ligament), longer operative times, and multilevel surgery were all at increased risk for SEH.[15]

Advantages of Inpatient/In-Hospital Treatment for Acute Postoperative Anterior Cervical Hematomas

The protocols for treating acute postoperative anterior cervical hematomas may include; (A) immediate opening

of wounds in the postoperative care unit (PACU) (i.e. for patients in severe acute distress, especially where intubation is extremely difficult), and (B) obtaining STAT postoperative MR scans followed by returns to the operating room to remove documented hematomas. Additionally, MO inpatients who develop postoperative AE, especially including increased focal swelling/edema, exacerbation of obstructive sleep apnea, and/or postoperative epidural hematomas (PEH) as inpatients/in-hospital settings, have 24/7 availability of anesthesiologists (i.e., to intubate, run codes and resuscitate), and surgeons (i.e. to evacuate anterior acute hematomas). Alternatively, after typical 4-7.5 hr. postoperative care unit (PACU) observation periods, Ambulatory Surgical Center (ASC) patients are sent to unmonitored floor beds for up to the remaining 23-hour stays, while Outpatient SurgiCenter (OSC) patients are discharged home. For ASC/OSC patients, cardiorespiratory arrests result in more devastating neurological sequelae and/or death (i.e. Advanced Cardiac Life Support (ACLS) Data Show Significant Brain Damage for CPR Delayed 4-6 minutes, and High Probability of Brain Damage if Delayed 6-10 minutes).

Two Case Studies of Acute Returns to the Operating Room Without MR Scans Missed Hematomas

Following ACDF, 2 case studies documented how immediate returns to the operating room without postoperative MR scans failed to correctly diagnose the locations of postoperative hematomas [Table 1].[7,18] In Hans *et al*. (2003) study, 2.5 hours following a C67 ACDF, the patient developed acute flaccid quadriplegia; they immediately returned to the operating room without a repeat MR to remove a presumed anterior C67 PEH.[7] However, when they failed to find the clot, they then obtained a STAT MR that demonstrated a posterior PEH that warranted an immediate C3-T3 laminectomy. In the second case (2016), following a C56 ACDF, the patient developed acute postoperative paraparesis; the immediate return to the operating room without an MR failed to reveal an anterior C56 PEH.[18] The patient subsequently underwent a STAT cervical/thoracic MR that demonstrated a thoracic subdural hematoma that was acutely treated with a thoracic laminectomy.

Patients With Fewer/More Minor Comorbidities Were "Carefully Selected" for ACDF Surgery in ASC/OSC

Several studies showed that patients with fewer/more minor comorbidities were "carefully selected" to undergo ACDF surgery in ASC/OSC, while most with MO/other major comorbidities were typically triaged to undergo ACDF surgery as inpatients [Table 1].[5,14,24] Garringer *et al*. (2010) retrospectively assessed unplanned readmissions within 48 postoperative hours in a population of 645 patients undergoing 1-level ACDF in ASC/OSC; 2 (0.3%) acutely developed postoperative spinal epidural hematomas diagnosed in postoperative care units (PACU) within 4-hour post-surgery windows.[5] However, there were 6 other unplanned readmissions that occurred following the 4-hour PACU observation period; 80% were for postoperative pain/nausea. Using a PearlDiver Database, Martin *et al*. (2018) evaluated the number/severity of postoperative adverse events occurring within 30 days of 18,386 ACDF performed in inpatient vs. outpatient settings (2007-2014).[14] There was a lower AE rate of 9.5% for ACDF performed as outpatients vs. an 18.6% incidence of AE for inpatients who had more severe comorbidities (i.e. higher incidence of obesity, older age, coronary, renal, and pulmonary disease). These authors concluded, "Appropriate patient selection is key, and the standard of care nationally for the comorbid patient remains inpatient admission." When Yerneni *et al*. (2020) evaluated the safety of performing ACDF in an outpatient setting (i.e. based on 21 review articles up to 2018), they determined that only; "...well-selected patients should undergo outpatient ACDF".[24] Notably, they specifically "selected" to perform inpatient ACDF procedures for those with greater/more severe comorbidities, typically including; significant obesity, older age, and myelopathy that predisposed these patients to higher reoperation rates, longer lengths of stay (LOS), and greater mortality. They concluded that those with greater comorbidities; "are likely not suitable (candidates) for outpatient ACDF."

Definition of Obesity and Morbid Obesity

The World Health Organization defines Obesity as Class II (>/= 35 kg/M2 + 2 comorbidities) vs. Morbid Obesity as Class III (>/= 40 kg/M2: MO World Health Organization) [Table 1].[2,3,6,9,12,13,16,22]

Greater Comorbidities in Obese/MO Patients Undergoing ACDF Lead to More Postoperative Adverse Events (AE)/Morbidity/Mortality

Multiple studies documented greater postoperative AE, morbidity, and mortality rates for obese/MO patients undergoing anterior cervical surgery, particularly ACDF [Table 1].[1,3,6,10,16,17,19,20] At 2 postoperative years in Chotai *et al*. (2016), MO Class II (BMI >/= 35 mg/M2) and Class III patients (40 kg/M2) exhibited greater comorbidities, more adverse events (AE), lower Quality-Adjusted Life Years (higher cost per QALY), and lower cost-effectiveness following ACDF surgery vs. non-obese patients.[1] In Epstein's review in 2017, most spine studies documented the increased risks of major AE for morbidly obese patients (i.e. Classes II or III) undergoing spine surgery.[3] Their higher risks included; poor quality preoperative studies, poor resolution of intraoperative films resulting in more wrong-level surgery, more vascular compromise (i.e., deep

venous thrombosis (DVT)/pulmonary embolism (PE)), more cardiac events, plexus/positioning injuries, blindness in the prone position, wound hematomas, seromas, and anesthetic AE (i.e. due to obstructive sleep apnea and/or edema/swelling). In Kalanithi *et al.* (2012), 1,455 MO patients demonstrated increases in the cost and incidence of AE out of 84,607 patients undergoing four types of spine fusions (i.e. anterior or posterior cervical fusion, anterior lumbar interbody fusion (ALIF) and posterior lumbar interbody fusion (PLIF) from California 2003-2007 (CA-SID) Healthcare Cost and Utilization Project's California State Inpatient Databases).[10] The MO patients demonstrated a 97% greater in-hospital complication rate (13.6% vs. 6.9% outpatient), a higher mortality rate, higher average hospital costs, and longer lengths of stay (LOS). Evaluating a NSQUIP database of 51,149 patients in 2020, Ottesen *et al.* found that both under and overweight (MO) patients were at higher risk following anterior cervical surgery for adverse perioperative events (i.e. 30-day AE, readmissions, postoperative infections and mortality from 2005-2016).[16] Qi *et al.* (2020) observed that obesity increased the incidence of AE for 156 obese patients (2010-2016) undergoing multilevel ACDF for cervical spondylotic myelopathy (CSM).[19] Major risk factors included; larger neck circumference, shorter neck length, higher BMI, longer surgical times, greater estimated blood loss, more multilevel disease, and greater severity of CSM.

As National Inpatient Survey (NIS) Databases Showed Increased Risks for Obese Patients Undergoing ACDF Surgery, These Should Be Performed as Inpatients/In-Hospitals

Two NIS studies documented that obesity increased the frequencies of adverse events following ACDF surgery that should, therefore, be performed as inpatients [Table 1].[17,20] Perez-Roman *et al.* (2021) observed a greater incidence of perioperative morbidity in obese patients undergoing ACDF in the National Inpatient Survey (NIS) 2004-2014 sample of 1,212,475 patients undergoing ACDF; 9.2% were obese, and this number increased from 5.8% in the earlier years to greater than 13.4% at the end of the study period.[17] Obesity in patients undergoing ACDF increased the rates of; dysphagia, new postoperative neurological deficits, respiratory depression, hematological/hemorrhagic adverse events, pulmonary embolism, and dural tears. The authors concluded that ACDF in obese patients should be performed as inpatients. Also utilizing a NIS database (2006-2010) involving 78,771 patients, Rogerson *et al.* (2021) identified multiple risk factors, including obesity, that contributed to adverse events/mortality following 1-2 level inpatient ACDF.[20] Early AE following ACDF were largely attributed to; obesity, renal disease, anemia, myelopathy, bleeding disorders, chronic obstructive pulmonary disease, obstructive sleep apnea, age over 65, and diabetes. The overall morbidity/adverse event (AE) rate was 3.73%, with the medical 3.13% frequency of AE. Here, the authors concluded: "Surgeons should consider these risk factors when deciding to perform ACDF surgery in an outpatient setting."

Greater Risks for Postoperative Hematomas in MO Patients Undergoing ACDF

In 2020, Epstein reviewed 11 studies looking at the frequency of postoperative hematomas following anterior cervical surgery (i.e. ACDF, ACF, and anterior cervical spine surgery (ACSS)) [Table 1].[4] A total of 44,030 patients were evaluated; these data included 4 large series and one National Surgical Quality Improvement Program (NSQUIP) database. Risk factors for postoperative hematomas included; morbid obesity, high or low BMI, DISH (Diffuse Idiopathic Skeletal Hyperostosis), OPLL, surgery lasting over 4 hours, heparin, multilevel surgery, preoperative ASA (American Society of Anesthesiologists) scores of >/= 3, prone surgery, smoking, anemia, age over 65, and myelopathy. The study emphasized the need for early diagnosis of postoperative hematomas to limit perioperative/postoperative morbidity and mortality.

Obese Patients Undergoing ACDF Typically Exhibited More Preoperative Comorbidities and Perioperative Adverse Event (AE) Requiring More Non-Routine Discharges

When Koo *et al.* (2021) looked at discharges for 17,385 patients from the National Inpatient (NIS) sample undergoing ACDF for CSM, they found 3035 (17.4%) were obese (i.e., vs. 14,350 who were not obese) [Table 1].[12] Obesity was an independent predictor of a 24.2% rate of non-routine discharges vs. a lower 16.6% incidence of non-routine discharges for those without obesity. Further, 43.5% of obese patients had three or more major preoperative comorbidities vs. a lower 28.1% incidence seen in non-obese patients. The greater comorbidities for obese patients likely contributed to their higher 14.3% frequency of AE vs 10.3% for non-obese patients.

MO Patients Undergoing ACDF Required Longer Operations But Without Higher Reoperation/Readmission Rates, Length of Stay (LOS) or Non-Routine Discharges

Gross *et al.* (2023) performed a 1-level ACDF study that included 670 patients operated on from 2010 to 2022; 413 (61.6%) patients were non-obese (BMI < 30), 226 (33.7%) were obese (BMI 30-39.9), while 31(4.6%) were MO (BMI >/= 40) [Table 1].[6] MO and obese patients undergoing ACDF required longer surgical procedures, but had no increased

reoperation/readmission rates, length of stay (LOS), or non routine discharges compared with non-obese patients.

General Impact of Bariatric Surgery on Spine Operations

In 2017, Epstein specifically looked at the increased risks for MO patients (i.e. Classes II and III) with prior histories of bariatric bypasses undergoing different spine operations [Table 1].[2] Within two years of BS surgery, spine patients exhibited vitamin D deficiency and significant losses in bone mineral density (BMD), which predisposed them to higher risks of spine/other fractures.

Utilizing PearlDiver Databases, Two Studies Showed Preoperative Bariatric Surgery (BS) Reduced AE/Morbidity/Mortality Rates for MO Patients Undergoing ACDF

Utilizing the PearlDiver Database, two studies showed that performing bariatric surgery in MO patients prior to ACDF decreased their postoperative AE/morbidity/mortality rates [Table 1].[9,13] With the PearlDiver Database (2007-2013) and 100% Standard Analytic Files (SAF 100), Malik *et al.*, (2021) compared the 90-day postoperative outcomes for 411 MO patients in Group I (BMI >/= 35 kg/M2) who had BS surgery within two years of ACDF vs. Group 2 patients (BMI >/= 35 kg/M2) undergoing ACDF without prior BS surgery.[13] MO patients with prior BS had fewer AE following ACDF (i.e., pulmonary embolism, coronary disease, renal disease, and 90-day readmission rates) vs. MO patients without BS. Similarly, using the PearlDiver Spine Database to analyze 160,166 patients, Joo *et al.* (2023) also found that BS surgery reduced the incidence of AE following ACDF Surgery (2010-2020).[9] They compared outcomes for non-obese (control patients) vs. 136 obese patients (i.e. BMI < 35 kg/M2m) vs. 343 MO patients (i.e. BMI >/= 35.). Those undergoing ACDF without BS and who were still MO had higher 90-day risks of pulmonary embolism, wound dehiscence, hematomas, and reoperation rates. Alternatively, those who had BS surgery and were no longer MO did not have an increased risk for AE/mortality following ACDF. Notably, the authors of both series recommended that MO patients consider undergoing BS surgery prior to ACDF to reduce perioperative/postoperative AE.[9,13]

Higher Risk of Dural Tears (DT) in Obese Patients Undergoing ACDF Excluding OPLL

Using the National Inpatient Sample (NIS 1998-2010) database for 1,261,140 patients undergoing ACDF, excluding those with OPLL, Kapadia *et al.* (2019) evaluated risk factors contributing to intraoperative DT [Table 1].[11] Risk factors identified in the 3048 (0.24%) patients sustaining intraoperative DT included; older age (ages 55-69, or above age 70), non-white patients, obesity, cervical spondylotic myelopathy (CSM) (i.e. not discs/radiculopathy), and hypertension, but not diabetes or hyperlipidemia. Notably, DT contributed to longer average LOS (6.0 days vs. 2.1 days without DT). Here, the authors recommended that obese patients with hypertension and obesity be optimized prior to surgery (i.e., with stringent weight loss and better blood pressure control) to help mitigate their incidence of intraoperative DT. They further supported performing these procedures as inpatients/in-hospitals.

Risk for Respiratory Pulmonary Complications (PRC) After ACDF Surgery and Preoperative Optimization Recommendations

Utilizing the (NIS (National Inpatient Sample Database 2016-2018) including 52,575 elective ACDF procedures, Hardman *et al.* (2022) found 1454 ACDF-related postoperative Respiratory Pulmonary Complications (RPC) [Table 1].[8] Factors contributing to the RPC rate included; obesity, older age, African American heritage, diabetes, hypertension, and multilevel surgery in urban hospital settings. Additional factors included; abscess angio-edema, laryngeal edema, vocal cord paralysis, dysphonia, pneumonia, and acute respiratory distress syndrome. The authors concluded; "Our study identified modifiable predictors of RPC after elective ACDF (e.g., obesity, diabetes), which can be used to guide preoperative patient optimization."

Bone Morphogenetic Protein (BMP) Used in Anterior Cervical Spine Surgery Increased AE Rates

Williams *et al.* (2011) compared the rates of postoperative AE for 55,862 patients undergoing spine fusions; one group of 11,933 patients received BMP (21%), while the remainder did not [Table 1].[23] The overall incidence of AE was increased to 5.8% by applying BMP vs. 2.4% without BMP. Notably, a higher 2.1% infection rate was seen with BMP vs. a lower 0.4% without. Specifically, the anterior cervical application of BMP significantly increased the AE rates for new/revision operations, but this did not hold true for posterior cervical procedures or thoracolumbar fusions utilizing BMP.

Increased Risks for MO Patients Undergoing 1-2 Level Anterior Cervical Disc Replacement Surgery

Subramanian *et al.* (2023) looked at risk factors that correlated with early readmissions and non-home postoperative discharges in NSQUIP (National Surgical Quality Improvement Program) patients undergoing 1-2 level anterior cervical disc replacement surgery (CDR) [Table 1].[22] They compared the impact of 919 MO Class II/III patients

(BMI >/= 35) vs. 1238 obese Class I patients (BMI 30-34.9 kg/M2) vs. 3,130 non-obese patients (BMI 18.5-29.9 kg/M2) for non-home discharges, and readmission rates.[22] Increased 30-day non-home discharge rates were observed for MO Class II/III (2.1%) patients vs. Class I (0.7%) patients vs. non-obese (0.5%) patients. Additionally, Class II/III MO patients showed higher 30-day readmission rates (2.1%) vs. obese (1.1%) vs. non-obese patients (0.5%).

CONCLUSION

MO patients (i.e. defined as Class II (BMI >/= 35 kg/M2) or Class III (BMI >/= 40 kg/M2) with their accompanying greater comorbidities exhibited higher perioperative/postoperative morbidity/mortality rates following anterior cervical surgery (i.e., predominantly ACDF). Therefore, shouldn't anterior cervical procedures performed in MO patients be performed as inpatients, within in-hospital settings?

Ethical approval

Institutional Review Board approval is not required.

Declaration of patient consent

Patients' consent not required as patients' identities were not disclosed or compromised.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

REFERENCES

1. Chotai S, Sielatycki JA, Parker SL, Sivaganesan A, Kay HL, Stonko DP, *et al*. Effect of obesity on cost per quality-adjusted life years gained following anterior cervical discectomy and fusion in elective degenerative pathology. Spine J 2016;16:1342-50.
2. Epstein NE. Bariatric bypasses contribute to loss of bone mineral density but reduce axial back pain in morbidly obese patients considering spine surgery. Surg Neurol Int 2017;8:13.
3. Epstein NE. More risks and complications for elective spine surgery in morbidly obese patients. Surg Neurol Int 2017;8:66.
4. Epstein NE. Frequency, recognition, and management of postoperative hematomas following anterior cervical spine surgery: A review. Surg Neurol Int 2020;11:356.
5. Garringer SM, Sasso RC. Safety of anterior cervical discectomy and fusion performed as outpatient surgery. Spinal Disord Tech 2010;23:439-43.
6. Gross EG, Laskay NM, Mooney J, McLeod MC, Atchley TJ, Estevez-Ordonez D, *et al*. Morbid obesity increases length of surgery in elective anterior cervical discectomy and fusion procedures but not readmission or reoperation rates: A cohort study. World Neurosurg 2023;173:e830-7.
7. Hans P, Delleuze PP, Born JD, Bonhomme VJ. Epidural hematoma after cervical spine surgery. Neurosurg Anesthesiol 2003;15:282-5.
8. Hardman M, Bhandarkar AR, Jarrah RM, Bydon M. Predictors of airway, respiratory, and pulmonary complications following elective anterior cervical discectomy and fusion, Clin Neurol Neurosurg 2022;217:107245.
9. Joo PY, Zhu JR, Rilhelm C, Tang K, Day W, Moran J, *et al*. Anterior cervical discectomy and fusion outcomes in patients with and without bariatric surgery-weight loss does make a difference. Spine (Phila Pa 1976) 2023;48:400-6.
10. Kalanithi P, Arrigo R, Boakye M. Morbid obesity increases cost and complication rates in spinal arthrodesis. Spine (Phila Pa 1976) 2012;37:982-8.
11. Kapadia BH, Decker SI, Boylan MR, Shah NV, Paulino CB. Risk factors for cerebrospinal fluid leak following anterior cervical discectomy and fusion. Clin Spine Surg 2019;32:E86-90.
12. Koo AB, Elsamadicy AA, Sarkozy M, David WB, Reeves BC, Hong CS, *et al*. Independent association of obesity and nonroutine discharge disposition after elective anterior cervical discectomy and fusion for cervical spondylotic myelopathy. World Neurosurg 2021;151:e950-60.
13. Malik AT, Noria S, Xu W, Retchin S, Yu ES, Khan SN. Bariatric surgery before elective anterior cervical discectomy and fusion (ACDF) in obese patients is associated with reduced risk of 90-day postoperative complications and readmissions. Clin Spine Surg 2021;34:171-5.
14. Martin CT, D'Oro A, Buser Z, Youssef JA, Park JB, Meisel HJ, *et al*. Trends and costs of anterior cervical discectomy and fusion: A comparison of inpatient and outpatient procedures. Iowa Orthop J 2018;38:167-76.
15. Miao W, Ma X, Liang D, Sun Y. Treatment of hematomas after anterior cervical spine surgery: A retrospective study of 15 cases. Neurochirurgie 2018;64:166-70.
16. Ottesen TD, Malpani R, Galivanche AR, Zogg CK, Varthi AG, Grauer JN. Underweight patients are at just as much risk as super morbidly obese patients when undergoing anterior cervical spine surgery. Spine J 2020;20:1085-95.
17. Perez-Roman RJ, McCarthy D, Luther EM, Lugo-Pico JG, Leon-Correa R, Gaztanaga W, *et al*. Effects of body mass index on perioperative outcomes in patients undergoing anterior cervical discectomy and fusion surgery. Neurospine 2021;18:79-86.
18. Protzman NM, Kapun J, Wagener C. Thoracic spinal subdural hematoma complicating anterior cervical discectomy and fusion: Case report. J Neurosurg Spine 2016;24:295-9.
19. Qi M, Xu C, Cao P, Tian Y, Chen H, Liu Y, *et al*. Does obesity affect outcomes of multilevel ACDF as a treatment for multilevel cervical spondylosis?: A retrospective study. Clin

Spine Surg 2020;33:E460-5.
20. Rogerson A, Aidlen J, Mason A, Pierce A, Tybor D, Salzler MJ. Predictors of inpatient morbidity and mortality after 1- and 2-level anterior cervical diskectomy and fusion based on the national inpatient sample database from 2006 through 2010. Orthopedics 2021;44:e675-81.
21. Schroeder GD, Hilibrand AS, Arnold PM, Rish DE, Wang JC, Gum JL, *et al*. Epidural hematoma following cervical spine surgery. Global Spine J 2017;7:120S-6.
22. Subramanian T, Shinn D, Shahi P, Akosman I, Amen T, Maayan O, *et al*. Severe obesity is an independent risk factor of early readmission and nonhome discharge after cervical disc replacement. Neurospine 2023;20:890-8.
23. Williams BJ, Smith JS, Fu KM, Hamilton DK, Polly DW Jr., Ames CP, *et al*. Does bone morphogenetic protein increase the incidence of perioperative complications in spinal fusion? A comparison of 55,862 cases of spinal fusion with and without bone morphogenetic protein. Spine (Phila Pa 1976) 2011;36:1685-91.
24. Yerneni K, Burke JF, Chunduru P, Molinaro AM, Riew KD, Traynelis VC, *et al*. Safety of outpatient anterior cervical discectomy and fusion: A systematic review and meta-analysis. Neurosurgery 2020;86:30-45.

How to cite this article: Epstein NE, Agulnick MA. Anterior cervical surgery for morbidly obese patients should be performed in-hospitals. Surg Neurol Int. 2024;15:2. doi: 10.25259/SNI_957_2023