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Epidural Analgesia after Liver Resection: A Comprehensive Audit on Failure Rates, Causes and Impact of an Advanced Practice Provider-Led Program

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Abstract

Background: Thoracic Epidural Analgesia (TEA) is recommended for pain control following hepatecomy. Recent data questioned this approach arguing increased risk of postoperative complications and Length of hospital Stay (LOS). It is unclear if such outcomes are related to TEA management, and whether a focused inpatient surgical service can mitigate adverse events.

Methods: A retrospective cohort study including patients having open liver resection at a high-volume center was performed (2016-2021). Patients were categorized into TEA and No-TEA groups, and overall outcomes compared. The primary outcome of the study was TEA failure rate. Univariate and multivariate logistic regression analysis were performed to examine the impact of an Advanced Practice Provider (APP)-led inpatient surgical service on TEA failure rates.

Results: A total of 517 patients were included; 361 in the TEA group (70%) and 156 in the No-TEA group (30%). There were no significant differences between the TEA and No-TEA groups in grade 3 to 4 postoperative complications (11.1% *vs.* 10.3%, p=0.78), median LOS (5 days [4-7] *vs.* 5 days [4-7]; p=0.8), and in overall textbook outcomes (66.7% *vs.* 70.5%, p=0.4). Failure rate was 26.5% and was significantly more common before as compared to after the APP-led program implementation (33.3% *vs.* 20.9%, p=0.008). On multivariate analysis, care under the APP-led program was associated with lower risk of TEA failure (OR 0.52 [95% CI 0.31-0.85], p=0.009).

Conclusion: TEA is safe for postoperative pain control after hepatectomy. Failure rates occur in one fourth of patients and can be minimized by implementing an APP-led focused hepatobiliary surgical inpatient service.

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Introduction

Postoperative pain control following abdominal cancer operations is an essential component of patient-centered cancer care, as it is associated with improved patient satisfaction, earlier recovery, decreased length of stay, decreased costs, and may have some impact on long-term oncologic outcomes – including survival [1,2]. In the setting of Hepatopancreatobiliary (HPB) surgery, different modes of perioperative analgesia have been described including Thoracic Epidural Analgesia (TEA), Intravenous Patient-Controlled Analgesia (IV PCA), and continuous infusion through wound catheters, intrathecal analgesia, and transversus abdominis plane block, among others [3]. Although it is currently controversial which should be the primary analgesia treatment, it is clear that postoperative pain control should include a multimodal approach, typically combining different systemic analgesic medications during the perioperative period – and with the added benefits of decreasing need for opiate utilization [4]. For liver surgery specifically, TEA has been traditionally recommended [3], and is currently included as the preferred option in fast-track programs for open liver resection - Enhanced Recover After Surgery (ERAS) protocols, in which the dominant mode (TEA) is used as part of a multimodal approach (i.e., in combination with preventive and opiate-sparing analgesia, including use of other medications) [5]. However, recent studies have brought to light limitations derived from TEA use, including higher rate of postoperative urinary tract infections [6], Acute Kidney Injury (AKI) [7], hypoperfusion [8], and a more recently described association with increased length of stay when compared to other non-epidural strategies [9]. These are important considerations when making decisions about the primary mode of postoperative pain control, particularly in the setting of emerging data supporting

other equally effective modes of analgesia [4]. Notwithstanding the development of new strategies, adoption of some of these is not universally feasible, and is often limited by expertise, time and/or costs required as an initial investment, not available at every institution. Most importantly, with TEA being a validated method for appropriate pain control, it is crucial to understand the patterns of TEA management (e.g., early Foley catheter removal, management of hypotension, titration of epidural infusion, etc.) that may be related to some of these adverse events [10,11] – prior to committing to other strategies that may require buy-in from stakeholders and overall extended times for rolling out the process of implementation and adoption [12]. While there are multiple analysis examining the overall efficacy of TEA, and comparing it to other modes of pain control, there are limited studies using direct patient-source data, evaluating the reasons for TEA failure in large cohorts of patients following hepatectomy. Based on this knowledge gap, the purpose of this study was to evaluate and compare related outcomes in patients having multimodal postoperative analgesia with and without TEA, and to examine and characterize epidural failure rates, using an internal audit approach for each individual patient. Additionally, we focused on evaluating the impact of implementing an APP-led inpatient hepatobiliary surgical service on TEA management and success, in a contemporary cohort of consecutive patients having liver resection.

Materials and Methods

This is a retrospective cohort study including patients having liver resection at Moffitt Cancer Center (MCC), the only NCI-designated comprehensive cancer center in Florida, serving patients with cancer across the southeastern US and nationally. The study was approved by the Study Review Committee of Moffitt Cancer Center and the Institutional Review Board at the University of South Florida.

Setting, study population and data collection

MCC is a high-volume center with >150 hepatobiliary operations done annually and performed by surgical oncologists with a focused practice on hepatobiliary surgery. All patients are discussed in a weekly hepatobiliary tumor board where treatment options are reviewed and decisions regarding next steps are outlined and initiated [13]. All patients having surgery are managed within the context of an ERAS pathway encompassing pre-, intra- and post-operative multidisciplinary components delivered through the surgical clinic team, and delivered through the surgical clinic team, nursing and the anesthesia service, including multi-modal analgesia (Table 1). Patients were identified from a prospectively collected database, and all consecutive subjects having liver resection for hepatobiliary tumors were included in the study (July 2016 – August 2021). Patients having liver resection using a minimally invasive approach (laparoscopic or robotic hepatectomy) were excluded. Patients were categorized based on type of primary postoperative analgesia mode into Thoracic Epidural Analgesia group (TEA) and No-TEA group (Figure 1). Other covariates such as demographic (age, gender, race, and ethnicity), clinical (comorbidities, liver function measures, cancer information, and intraoperative surgical data) and outcome variables were included for the analysis.

Outcomes

Overall outcomes were compared between the TEA and No-TEA groups including: median time to clear liquid diet (days), median Length of Stay (LOS) (days), and occurrence of specific complications - UTI, AKI and Textbook Outcome (TO). TO was defined using validated component criteria as a postoperative course characterized by: No 90-day-Clavien-Dindo Grade III or IV complication, -unplanned readmission, -unplanned reoperation, or -mortality and LOS<75th percentile [14,15]. The primary outcome of interest was TEA failure, which was defined as failure to control postoperative pain AND the need for starting an additional pain control modality – usually initiation of IV PCA, regardless of continuation with TEA. Secondary outcomes were related to the cause of TEA failure. Both primary and secondary outcomes were compared based on the existing model for inpatient hepatobiliary surgery care: APP-led versus standard practice.

Role of advance practice providers – APP-led structure

Starting on July 2015 (1 year prior to the study cohort), ERAS pathways were implemented for all patients having liver resection, including use of TEA. Patients were admitted postoperatively to the surgical ward and managed by rotating residents and fellows under the guidance of the treating surgeon. TEA was managed by rotating anesthesia team members, without a formal Acute Pain Service (APS). In 2018 (2 years after study cohort) an APP-led hepatobiliary service was developed. This was part of a global effort implemented for patients having gastrointestinal cancer operations at MCC; results from this initiative have been published and described previously [16]. In short, in addition to leading all aspects of ERAS and other non-ERAS components of postoperative surgical care, the hepatobiliary inpatient APP team partnered with the anesthesia service to develop and learn management principles for TEA care; including understanding the different system components, recognition of severe side effects, malfunction, and troubleshooting with available solutions to optimize pain control and minimize side effects – including titration of the medications infused. Given the lack of an APS, clear lines of communication were developed and emphasized between the hepatobiliary APPs and the anesthesia service. Supplemental training sessions for the APPs directed by anesthesia faculty, on pain control and TEA management were scheduled iteratively and protocols of care were sequentially developed. The Anesthesia service continued to round daily and guide management for the TEA, supported by the APP-led program, as there was no formal APS established.

Statistical analysis

Descriptive statistics are presented as frequency for categorical variables and median with Interquartile Range (IQR) for continuous variables. Univariate analyses were performed using Chi-square, Fisher's exact test or Wilcoxon rank-sum test, as appropriate. Multivariable logistic regression modeling was performed to identify factors associated with TEA failure. A multivariable model was created first using all variables with a $p<0.2$ and/or having a plausible association with the primary outcome; those which were insignificant ($p>0.05$) were sequentially removed to create the final reduced multivariable model. All statistical analyses were performed using Stata version 14.

Results

In all, 577 patients having liver resection during the study period were identified and 517 patients met inclusion criteria. Most patients were treated with TEA (361–70%), with the remainder in the No-TEA group (156–30%) managed with IV PCA as the dominant mode (132–85%) and other strategies used less commonly (combined IV PCA and TAP block= 16–10%; and a combination of oral medications with IV analgesics *via* pushes as needed in 8 patients – 5%) (Figure

Table 1: ERAS pathway used for patients having liver resection at the Hepatobiliary Service in Moffitt Cancer Center – including multimodal analgesia perioperative strategy (bolded).

Time period	Domain	Specific measure
Preoperative	• Education	Procedure, pathways and expectations setting.
	• Bowel preparation	No bowel preparation.
	• Preoperative fasting	Clear liquid diet upto 2h prior to surgery.
	• CHO load	CHO load drink 12h and 3h prior to surgery.
	• PONV prophylaxis	Aprepitant/Fosaprepitant for Apfel≥ 4.
	• Anxiolytics	Avoid benzodiazepines if possible.
	• **Preemptive analgesia**	Celebrex 400 mg PO, Gabapentin 600 mg PO, Tramadol 300mg PO, Acetaminophen 1000 mg PO.
	• **Regional analgesia**	Thoracic epidural catheter placement preferred.
	• Fluid management	Placement of 2 peripheal IV lines Saline-lock.
	• DVT/PE prophylaxis	TEDs and SCDs Heparin 5000U sq after epidural placement.
Intraoperative	• Steroids	Decadron 4 mg IV after induction.
	• Fluid management	Goal-directed therapy. Limit fluids. Stroke volume variation continuous measurement – target 12-15 pre-transection. Bolus with Albumin 5%.
	• Normothermia	Bair-hugger, warm fluids, low gas flows. Temperature target ≥ 36ºC.
	• Glycemic control	Insulin as needed. Target Glucose <180 mg/dl.
	• Tubes & Drains	Orogastric tube for during surgery & removed at conclusion. Selective drain placement.
	• **Opiate-sparing analgesia**	Acetaminophen. Avoid opiates during the operation.
	• **Regional analgesia**	Epidural preferred. Start infusion with ropivacaine 0.1% 3-5ml/h, if blood pressure tolerates. No boluses. If epidural not placed, consider regional TAP block at conclusion.
	• **Anesthesia management**	Total intravenous anesthesia (TIVA) preferred with propofol, dexmedetomidine, ketamine, lidocaine. Minimize volatile agents.
Postoperative	• **Opioid-sparing analgesia**	Celebrex, Acetaminophen IV, Gabapentin scheduled. Tramadol as needed for severe pain.
	• **Regional analgesia**	Epidural infusion and prn. Remove catheter on POP day 2-3 once tolerating regular diet.
	• Tubes & Drains	No NGT. Early removal of selectively placed drain.
	• Fluid management	Crystalloids 100cc/h × 24 hours followed by 50cc/h × 24-48 hours followed by Heplock.
	• Diet	Clear liquid diet day1. Regular diet day 2.
	• Ambulation	Sit at bedside day 0. Frequent ambulation at least x4/day starting day1.
	• Foley removal	Day 1 for all females and young males (<65). Day 2-3 for older males – at time of epidural catheter removal.
Discharge criteria	• No IV fluid support • No IV medications • Tolerating regular diet – solid foods • Ambulating by self – to preoperative level independence • Laboratory results trending towards normal levels	

1). Table 2 summarizes baseline demographic, clinical and surgical characteristics by TEA use. Notably, patients in the No-TEA group had a higher proportion of patients with ASA 3 or 4 scores (68% *vs.* 55%, P=0.007) and were less likely to have procedures that included vascular and/or bile duct resection (2.6% *vs.* 7.2%, p=0.04), with no other significant differences between the TEA and No-TEA groups.

Outcomes in TEA and no-TEA groups

Table 3 summarizes relevant outcomes for the whole cohort

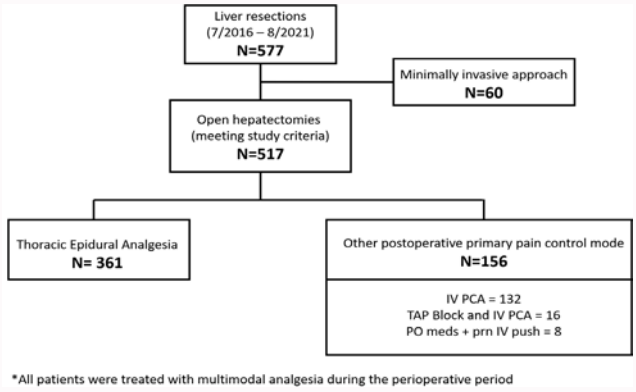

Figure 1: STROBE Study cohort selection.

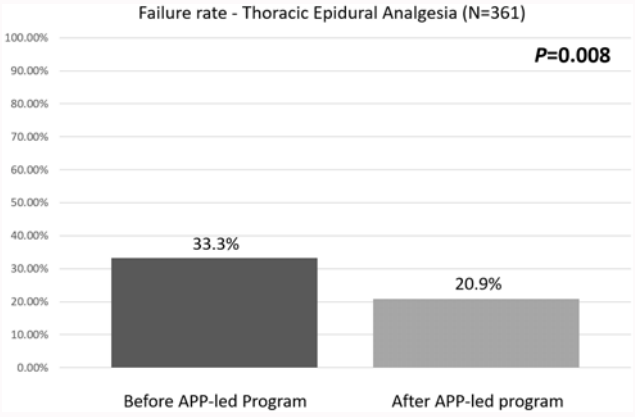

Figure 2: Thoracic epidural analgesia failure rates – before and after implementation of the APP-led program.

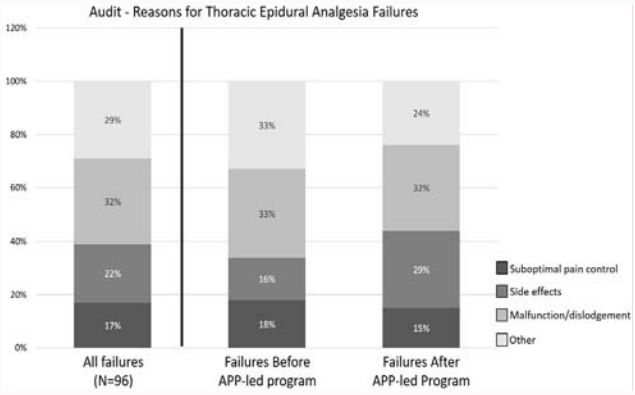

Figure 3: Reason for thoracic epidural failure by inpatient service care model - Before and After APP-led program implementation.

and by TEA group. There was no statistically significant difference between both groups in relation to time to clear liquid diets initiation or overall length of hospital stay (p>0.05 for both). Similarly, there were no significant differences in the incidence of UTI, or 90-day- Grade 3-4 Clavien-Dindo postoperative complications, -readmissions or -mortality. Though not statistically significant, there was trend towards increased risk of AKI in the TEA group (5.8% *vs.* 2.6%, p=0.12). The composite measure of textbook outcomes was also equivalent for both groups, without any significant differences observed (66.7% in the TEA group *vs.* 70.5% in the No-TEA group, p=0.4).

Primary outcome – TEA failure, causes & Impact of APP-led structure

Among the 361 patients treated with TEA, a total of 96 (26.5%) met criteria for epidural failure. On unadjusted comparison, epidural failure rate was significantly higher in the earlier period as compared to the period in which the APP-led program was already implemented (33.3% *vs.* 20.9%, p=0.008) (Figure 2). When evaluating the most common reasons for failure for the whole population (96 patients), malfunction of the epidural catheter (including dislodgement, leak, or other system issues such as connector problems or rupture of the catheter) was the most common reason (32%). Suboptimal pain control (17%) and problems related to side effects (predominantly hypotension) (22%) were closely distributed, with other reasons accounting for close to a third of the failure rates (29%) - including specific reasons such as: Prolonged hospitalization requiring other means of pain control, clinical decision and unknown reasons (not documented). Lastly, when comparing the reasons for TEA failure between the two time periods (before and after APP-led Program implementation), there was no significant differences (Figure 3). On univariate analysis, patients with TEA failure were more commonly <70 years (p=0.05), with prior abdominal operations (p=0.01), normal liver function (p=0.03), and with higher proportion of liver resection combined with other visceral resections (p=0.02). After multivariate logistic regression patients' age, ASA score, prior abdominal operation and time period without an APP-led program were each independent predictors of TEA failure (Table 4).

Discussion

The focus of this study was to compare postoperative outcomes following liver resection in patients receiving multimodal analgesia with or without TEA, and to examine and characterize TEA failure in the context of a structured APP-led inpatient hepatobiliary surgery service. Exploring efficacy of TEA in this context can help guide decisions of TEA use over other novel alternatives, particularly as the latter may require additional investments from the institution and where the true added benefit may be overcome by optimizing TEA daily management by a structured team. Our analysis yielded interesting and important findings. First, we found no difference in specific adverse outcomes between TEA and other modes of pain control, specifically the overall LOS and textbook outcomes, both measures of recovery, were equivalent in both groups. Second, we found an overall TEA failure rate of 26.5%, and were able to identify specific patient and clinical characteristics associated with increased risk of failure: Younger patients (<70 y), ASA score 3 to 4 and no prior abdominal operations. Most importantly, we found that daily management of TEA using a team approach with partnering of the anesthesia service and a dedicated APP-led inpatient surgical service was associated with lower rates of TEA failure overall (20.9% vs. 33.3%, p=0.008), an association that persisted after multivariate analysis (OR 0.52 [0.31-0.85]; p=0.009). These findings are notable because they help identify patients that are at higher risk of TEA failure, for whom a different strategy may be considered, and highlight the benefits of an APP-led service, which is a common and reproducible approach in current inpatient surgical care, and one that can help mitigate different types of TEA failures. Among the findings from this study, we were able to demonstrate overall equivalent outcomes - and specifically no increased adverse events - in patients with TEA as compared to those in the No-TEA group, with the latter group predominantly composed of patients receiving IV PCA as their primary analgesic mode. These findings are

Table 2: Baseline and clinical characteristics of patients having liver resection, classified by primary mode of perioperative pain control strategy (Note: all patients were treated with multimodal analgesia perioperatively) (n=517).

Characteristics	All (n=517)	Epidural (n=361)	No epidural (n=156)	P-value
Demographics				
Median age (25th, 75th percentile)	62 (54-70)	62 (53-70)	64 (56-70)	0.25
Age ≥ 70	143 (27.7)	99 (27.4)	44 (28.2)	0.86
Gender: Male	245 (47.4)	174 (48.2)	71 (45.5)	0.57
Race				0.26
White	445 (86.1)	311 (86.2)	134 (85.9)	
Black	42 (8.1)	26 (7.2)	16 (10.3)	
Other/Unknown	30 (5.8)	24 (6.7)	6 (3.9)	
Ethnicity: Hispanic	45 (8.7)	32 (8.9)	13 (8.3)	0.84
Comorbidities				
ASA score: 3/4	305 (59.0)	199 (55.1)	106 (68.0)	0.007
Charlson-Deyo comorbidity score*				0.28
0-2	491 (95.0)	340 (94.2)	151 (96.8)	
≥ 3	26 (5.0)	21 (5.8)	5 (3.2)	
ECOG Performance status				0.13
0	469 (90.7)	333 (92.4)	136 (87.2)	
1	45 (8.7)	26 (7.2)	19 (12.2)	
≥ 2	3 (0.6)	2 (0.6)	1 (0.6)	
Obesity	191 (36.9)	130 (36.0)	61 (39.1)	0.50
Diabetes	77 (14.9)	59 (16.3)	18 (11.5)	0.16
Past abdominal surgery	373 (72.3)	258 (71.7)	115 (73.7)	0.63
Liver characteristics				
Cirrhosis**	26 (5.0)	18 (5.0)	8 (5.1)	0.96
Non-alcoholic steatohepatitis	64 (12.4)	50 (13.9)	14 (9.0)	0.12
Chronic liver disease				
Hepatitis B	7 (1.4)	6 (1.7)	1 (0.6)	0.68
Hepatitis C	24 (4.6)	17 (4.7)	7 (4.5)	0.91
ALBI grade A1	463 (89.6)	322 (89.2)	141 (90.4)	0.69
Cancer characteristics				
Cancer type				0.20
HCC	44 (8.5)	32 (8.9)	12 (7.7)	
Biliary tract cancer	73 (14.1)	47 (13.0)	26 (16.7)	
CRLM	207 (40.0)	147 (40.7)	60 (38.5)	
NETLM	122 (23.6)	92 (25.5)	30 (19.2)	
Other	71 (13.7)	43 (11.9)	28 (18.0)	
Metastatic disease	377 (72.9)	264 (73.1)	113 (72.4)	0.87
Neoadjuvant chemotherapy	280 (54.2)	199 (55.1)	81 (51.9)	0.50
Surgical characteristics				
Incision				0.12
Midline	276 (53.4)	197 (54.6)	79 (50.6)	
Right subcostal	121 (23.4)	78 (21.6)	43 (27.6)	
Modified Makuuchi	81 (15.7)	53 (14.7)	28 (18.0)	
Right subcostal with midline and/or left extension	14 (2.7)	11 (3.1)	3 (1.9)	
Not specified	25 (4.8)	22 (6.1)	3 (1.9)	
Major hepatectomy	190 (36.8)	133 (36.8)	57 (36.5)	0.95
Combined visceral resection	126 (24.4)	87 (24.1)	39 (25.0)	0.83
Vascular/bile duct resection	30 (5.8)	26 (7.2)	4 (2.6)	0.041

Where IV PCA: Intravenous Patient-Controlled Analgesia

Percentages represent proportions within corresponding column category unless otherwise specified

*Excludes cancer diagnosis

**All patients with cirrhosis were Childs-Pugh class A

Table 3: Postoperative outcomes following liver resection, by TEA use (N=517).

	All (N=517)	Epidural (N=361)	No epidural (N=156)	P-value
Measures of recovery				
Median time to clear liquid diet (days)	1 (1-2)	1 (1-2)	1 (1-2)	0.51
Median length of stay (LOS – days)	5 (4-7)	5 (4-7)	5 (4-7)	0.8
Postoperative complications				
Incidence of urinary tract infection	39 (7.5%)	29 (8%)	10 (6.4%)	0.52
Incidence of acute kidney injury	25 (4.8%)	21 (5.8%)	4 (2.6%)	0.12
90-day Clavien-Dindo complications ≥ 3	56 (10.8%)	40 (11.1%)	16 (10.3%)	0.78
90-day readmissions	57 (11%)	40 (11.1%)	17 (10.9%)	0.95
90-day mortality	6 (1.2%)	4 (1.1%)	2 (1.3%)	1
Composite outcomes				
Textbook outcome	**351 (67.9%)**	**241 (66.7%)**	**110 (70.5%)**	**0.4**

Table 4: Independent predictors of thoracic epidural analgesia failure following liver resection (N=517).

Predictors	Odds ratio (95% CI)	P-value
Age ≥ 70	0.55 (0.31-0.99)	0.049
ASA score: 3-5	1.83 (1.09-3.05)	0.021
Past abdominal surgery	0.57 (0.34-0.97)	0.039
APP-led Program	0.52 (0.31-0.85)	0.009

in line with other studies explicitly comparing TEA to IV PCA following hepatectomy; in a randomized trial by Aloia et al., TEA and IV PCA had equivalent outcomes in relation to postoperative complications, LOS and readmissions, while the efficacy on pain control, measured by patient-reported 1-10 Likert scale was better for the TEA group [1]. Similarly, a recent meta-analysis evaluating efficacy and safety in TEA and IV PCA after liver resection also reported equivalent adverse events and LOS, while improved pain control with TEA group [17]. While the reports emphasizing the association of TEA with adverse events such as UTI or increased LOS are important, the presented data and the findings from our study provide robust evidence against such associations. One of such studies, published by our own group, found a higher risk of UTI in patients with TEA using a Hospital-Level National Database (NSQIP) [6]. At a population level, it may be that TEA are associated with increased risk of UTI, but as discussed in the cited manuscript, this may be indirectly related to the TEA, and more so as a result of urinary indwelling catheter practices across different hospitals. In this study, with a standardized perioperative ERAS protocol, which includes early urinary catheter removal, and supported by a dedicated APP-led team, we did not observe a higher incidence of UTIs. Similarly, the study by Kone et al., in which TEA was associated with increased LOS in patients in the NSQIP database, practices for postoperative care were heterogeneous, and while their findings may represent a more global perspective, it does not account for practice patterns within established benchmarks [9]. These findings have not been replicated in existing randomized trials, meta-analysis or in the results from this study, where management of patients is done within structured algorithms (including TEA care) [18,19]. As such, we believe that our results further support the safety profile of TEA use in patients with liver resection (in comparison to other strategies – particularly when compared to IV PCA), and their use should not be limited based on the misconception of increase risk of adverse events. Further, the safety of TEA is likely enhanced when managed by a dedicated team with expertise in both liver resection pathways and TEA management. Our primary outcome of interest was TEA failure rate. We found this to be significant occurring in up to 1/4 of all patients. However, it should be noted that we decided to use a very liberal definition for TEA failure, with the purpose of capturing all potential issues around TEA analgesia, even if they did not represent true failure – i.e., some patients recorded as failure due to addition of IV PCA, may have had continuation of their TEA, and ultimately received improved pain control with the combined therapy, while minimizing the consumption of total Opiate Morphine Equivalents (OME) during the postoperative period. This outcomes measure (OME) is in fact, one of the most used outcomes to define success when evaluating TEA or other regional approaches [20]. While our definition of TEA failure may have overinflated the true epidural failures, using such definition provided us the opportunity to examine and audit the TEA function throughout the hospital stay. Specifically, we were able to identify different categories of "problems" with the TEA use, - spanning across efficacy, side effects, and mechanical malfunction of the catheters/systems, among others. This is critical as it provides additional information when considering quality improvement projects, as the target areas for optimization can be easily identified and targeted. It also provides a more comprehensive review of TEA function, as compared to published reports, in which investigators focus on TEA placement and/or failure to accomplish appropriate catheter location, and hence poor function – low efficacy [21-23]. In this study, we found that when establishing the APP-led team, and in partnership with the anesthesia service, the team approach resulted in a significant decrease in TEA failure rates, that encompass overall drop in "problems" across all categories. The findings related to the impact of an APP-led hepatobiliary surgery service are particularly noteworthy. The use of TEA as a regional analgesia strategy relies heavily not only on the insertion and initial infusion dose, but also on day-to-day management including infusion titration and troubleshooting for side effects- and efficacy-related symptoms [24]. This typically is structured within an acute pain service that guides, oversees and makes hour-to-hour decision derived from expertise and continuous availability. Such services have been well studied and advocated for improving postoperative pain in patients having major abdominal cancer operations [25]. Our approach of integrating the anesthesia service (without the need for a formal acute pain service), with an APP-led inpatient surgical team provides an alternative (and arguably enhanced) approach optimize TEA management and pain control, by elevating the expertise and

skills in team members directly interfacing with patients (APPs), while having support and back-up from the anesthesia service providing the specialized expertise. We strongly believe that this model fulfills many of the outlined requirements for postoperative pain management [26], while minimizing added costs in resources and time to the anesthesia staff and the institution as a whole. Further, prior to considering adopting a more novel, questionable better primary analgesic mode, this model provides a way to optimize the use of TEA to a higher degree, cost-efficient, in a way that may be equally or more effective to other strategies. Having said that, it is still important to continuously evaluate emerging analgesic strategies, and tailor each approach to the individual patient needs. This study provides a way to better define which patients are likely to benefit the most from TEA, and select out those that may have more cost-effective benefits from such newer approaches [27-29]. This study has inherent limitations including those related to selection bias, derived from its retrospective nature. Further, our approach was to focus on a very inclusive definition of TEA failure that limited the ability to better describe the actual efficacy of TEA using patient-reported outcomes and measures of pain control. However out goal was to examine and characterize failure so as to highlight the importance of TEA management throughout the whole hospitalization. Lastly, our study is limited to the practices within an NCI-designated high-volume center. However, we present data derived from a large cohort and under standardized protocols of care that should serve as a blueprint for those treating patients having liver resection for cancer.

In conclusion, this study supports the safety profile of TEA as a primary mode for postoperative pain control following liver resection, in the context of contemporary perioperative care including ERAS pathways and multimodal analgesia. We found that approximately 25% of patients with TEA have problems related to this regional strategy, and that integrating care with the anesthesia service and a focused inpatient surgical service (APP-led in this case) provides the opportunity to optimize the care of TEA and decrease overall failure rates. This provides a model to deliver perioperative pain control for this population, and a potential benchmark to compare against novel emerging strategies.

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