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Clinical Study

Trends in the use of pulmonary artery catheterization in the aneurysmal subarachnoid hemorrhage population

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ABSTRACT

Use of the pulmonary artery catheter (PAC) has been controversial since the late 1980s. Multi-center observational and randomized controlled trials (RCTs) have concluded that PACs fail to decrease mortality. Subsequently, studies have looked for a decline in PAC use that corresponds to the literature and have indeed found that it exists. However, none to date have looked primarily at trends in the aneurysmal subarachnoid hemorrhage (aSAH) population. This study uses the Nationwide Inpatient Sample (NIS) from 2000–2010 to identify trends in PAC use among patients with aSAH. Trend analysis was assessed using a multivariable regression model with a calculation of slope of PAC frequency over time for pre-2005 and post-2005. Trends in mortality and routine discharge were also assessed for the same time period. 363,096 SAH patients were extrapolated using survey weights, of whom 6,988 had a PAC. Over time, PAC use declined, with a significant downward shift in the year 2005. Analyses also showed a decrease in mortality over the same time period. Our results show that PAC use among patients with aSAH decreased from 2000 to 2010. Similar to other studies, the decline appears to be temporally related to RCTs that showed a lack of benefit from PAC. Studies such as these have the potential to influence clinical practice through illumination of shifting opinions and approaches.

1. Introduction

The Swan–Ganz pulmonary artery catheter (PAC) was introduced in 1970 by Jeremy Swan and William Ganz [1]. Not long after its introduction, the PAC became widespread in critical care units due to the advantages it held over conventional catheters of the time [2]. Placement was relatively quick and straightforward, and physicians could use quantitative hemodynamic data, such as cardiac output and pulmonary capillary wedge pressure, to guide treatment, with the aim of reducing mortality [2,3]. In 2000, it was estimated that 1.5 million PACs were sold in the USA, with 30% used in cardiac surgery, 30% in coronary care units and cardiac catheter laboratories, 25% in high-risk surgical and trauma patients, and 15% in medical intensive care units (ICUs) [4,5].

One population in which PACs have been used is the aneurysmal subarachnoid hemorrhage (aSAH) population. aSAH is a potentially devastating event that accounts for approximately one quarter of cerebrovascular deaths and results in significant short- and long-term morbidity [6–9]. Following an aSAH, PACs provide insight into hemodynamic status that may guide management and treatment in the ICU. Hemodynamic monitoring and control is critical in determining a balance between cerebral perfusion and cardiac function, and many physicians rely on fluid monitoring systems to guide goal-directed fluid and vasopressor therapy [6,10–13]. These measurements allow for evaluation of hemodynamic changes that occur in the context of hemodynamic augmentation therapy, a mainstay in the treatment of cerebral vasospasm, a major complication seen in almost 70% of patients within the first two weeks [14].

PACs were once heavily used and supported. However, the widespread utility of PACs came into question in the late 1980s, when Robin et al. noted an absence of effectiveness in light of seemingly high associated morbidity and mortality [15]. Later in 1996, a multi-center observational study suggested that PAC use was associated with increased mortality, and an accompanying editorial recommended a randomized controlled trial (RCT) be performed otherwise a moratorium be placed on PACs [16,17]. In following years, a number of RCTs were conducted which generally concluded that PACs offered no reduction in mortality for a range

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of critically-ill patient populations [2]. Subsequently, several studies demonstrated a decline in PAC use [2,18]. However, to our knowledge, no study has examined these trends in the aSAH population. This study uses the Nationwide Inpatient Sample (NIS) from 2000–2010 to identify trends in PAC use among patients with aSAH.

2. Methods

2.1. Patient sample

This study uses inpatient hospital discharge data from 2000 to 2010 in the Healthcare Cost and Utilization Project (HCUP) NIS database (http://www.hcupus.ahrq.gov/nisoverview.jsp), the largest publicly available, all-payer inpatient database in the US. The NIS database contains data from over 1000 hospitals, representing 20% of all US hospital discharges. National estimates were obtained using weights applied as indicated in the HCUP–NIS guide for calculating NIS variances.

Cases of aSAH were identified using International Classification of Diseases, Ninth Revision; Clinical Modification (ICD-9-CM) (430.00). Two populations were created for analysis. For the purpose of outcomes analysis after PAC, the first group of admissions was created from patients with aSAH who underwent placement of one of the following: pressure monitor (89.63), wedge monitor (89.64), venous gas monitor (89.66), or cardiac output monitor (89.67, 89.68). Patients were excluded if they had a diagnosis of an arteriovenous malformation (AVM) or fistula (873.0–873.9), or head trauma (800.00–801.99, 803.00–804.99, 850.00–854.19, 873.00–873.90, 747.81) or if they had fistula repair (39.53), or stereotactic radiosurgery (92.30). A second group of admissions was created from all patients with aSAH for the purpose of comparing demographic data between PAC recipients and those without and assessing PAC usage over time.

Routine discharge was defined as a discharge home or to the care of law enforcement.

2.2. Statistical analysis

The primary goal was to assess the trend of PAC usage over time from 2000 to 2010. Trend analysis was assessed using a multivariable regression model with a calculation of slope of PAC, routine discharge, and mortality frequency over time. The predicting factors included patient-level factors: race, payment type, comorbidity, sex, and age category; hospital-level factors: region, location, teaching status, bed size; admission status-level factors: admission source and admission type.

The descriptive result was estimated using the "surveymean" procedure for applying the survey weight. The association between predicting factors and outcome was assessed by the rate ratio estimated through multivariate Poisson regression (the GLIMMIX procedure). The percent change in outcomes was assessed using "The surveylogistic procedure". All descriptive and regression analyses and procedures were performed using SAS software, version 9.4 (SAS Institute, Cary, USA).

3. Results

363,096 aSAH patients were extrapolated using survey weights, of which 6,988 had a PAC placed. The majority of patients receiving PAC were white, privately insured, female, over 60 years of age, and admitted as emergency cases into a large urban teaching hospital (Table 1). Length of stay averaged 11.65 days for those without PAC and 18.9 for those with PAC. Mortality in the PAC group was 31.4%. Over time, the use of PACs has been decreasing, with a significant downward shift in the year 2005 (Fig. 1).

Table 1
Patient demographics. Demographics for the 363,096 aneurysmal subarachnoid hemorrhage patients extrapolated from the National Inpatient Sample database between the years 2000 and 2010

Variable	Number	No PAC		PAC	
Race					
Asian/Pacific Islander	10895	10696	98.17%	199	1.83%
Black	40412	39743	98.34%	669	1.66%
Hispanic	32218	31660	98.27%	558	1.73%
Native American	992	962	96.98%	30	3.02%
Other	10024	9875	98.51%	149	1.49%
White	177267	173468	97.86%	3799	2.14%
Missing	91385	89800	98.27%	1584	1.73%
Payer status					
Medicare	41210	40277	97.74%	933	2.26%
Medicaid	129538	127716	98.59%	1821	1.41%
No charge	2431	2363	97.20%	67	2.76%
Other	13281	12995	97.85%	286	2.15%
Private including HMO	146146	142796	97.71%	3350	2.29%
Self-Pay	29789	29264	98.24%	525	1.76%
Missing	798	793	99.37%	5	0.63%
Age					
40–60 yrs old	48108	47157	98.02%	951	1.98%
>60 yrs old	156572	152897	97.65%	3675	2.35%
<40 yrs old	158512	156151	98.51%	2361	1.49%
Admission source					
Another hospital	52829	51385	97.27%	1444	2.73%
Court/law enforcement	92	92	100.00%	0	0.00%
Emergency Room	158780	155236	97.77%	3544	2.23%
Other facility including long term care	8646	8512	98.45%	134	1.55%
Routine	50560	49556	98.01%	1004	1.99%
Missing	92285	91423	99.07%	862	0.93%
Admission type					
Elective	29400	28964	98.52%	435	1.48%
Emergency	209947	205827	98.04%	4120	1.96%
Trauma center/newborn	1759	1708	97.10%	51	2.90%
Urgent	72654	71352	98.21%	1302	1.79%
Missing	49068	47989	97.80%	1079	2.20%
Comorbidities					
0 comorbidities	112064	109558	97.76%	2506	2.24%
1 comorbidity	78807	77795	98.72%	1012	1.28%
2 comorbidities	172322	168851	97.99%	3470	2.01%
Sex					
Female	222182	217526	97.90%	4656	2.10%
Male	140134	137803	98.34%	2332	1.66%
Missing	876	876	100.00%	0	0.00%
Hospital bed size					
Large	273399	267931	98.00%	5467	2.00%
Medium	65868	64620	98.11%	1248	1.89%
Small	21953	21685	98.78%	268	1.22%
Missing	1972	1968	99.80%	5	0.25%
Hospital location					
Rural	17279	17122	99.09%	157	0.91%
Urban	343941	337115	98.02%	6826	1.98%
Missing	1972	1968	99.80%	5	0.25%
Hospital region					
Midwest	79065	77606	98.15%	1459	1.85%
Northeast	64709	63407	97.99%	1303	2.01%
South	138422	136007	98.26%	2414	1.74%
West	80996	79184	97.76%	1812	2.24%
Teaching status					
Nonteaching	107183	105451	98.38%	1732	1.62%
Teaching	254037	248786	97.93%	5251	2.07%
Missing	1972	1968	99.80%	5	0.25%

HMO = Health Maintenance Organization, PAC = pulmonary artery catheter.

3.1. Trend analysis

Looking at PAC frequency without any adjustment, there is a decline from 3.56% of aSAH patients receiving PAC in 2000 to