Doing Our Part to Conserve Resources

Determining Whether All Personal Protective Equipment Is Mandatory for Closed Reduction and Percutaneous Pinning of Supracondylar Humeral Fractures

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Background: Closed reduction and percutaneous pinning (CRPP) of supracondylar humeral fractures is one of the most common procedures performed in pediatric orthopaedics. The use of full, standard preparation and draping with standard personal protective equipment (PPE) may not be necessary during this procedure. This is of particular interest in the current climate as we face unprecedented PPE shortages due to the current COVID-19 pandemic.

Methods: This is a retrospective chart review of 1,270 patients treated with CRPP of a supracondylar humeral fracture at 2 metropolitan pediatric centers by 10 fellowship-trained pediatric orthopaedic surgeons. One surgeon in the group did not wear a mask when performing CRPP of supracondylar humeral fractures, and multiple surgeons in the group utilized a semisterile preparation technique (no sterile gown or drapes). Infectious outcomes were compared between 2 groups: full sterile preparation and semisterile preparation. We additionally analyzed a subgroup of patients who had semisterile preparation without surgeon mask use. Hospital cost data were used to estimate annual cost savings with the adoption of the semisterile technique.

Results: In this study, 1,270 patients who underwent CRPP of a supracondylar humeral fracture and met inclusion criteria were identified. There were 3 deep infections (0.24%). These infections all occurred in the group using full sterile preparation and surgical masks. No clinically relevant pin-track infections were noted. There were no known surgeon occupational exposures to bodily fluid. It is estimated that national adoption of this technique in the United States could save between 18,612 and 22,162 gowns and masks with costs savings of $3.7 million to $4.4 million annually.

Conclusions: We currently face critical shortages of PPE due to the COVID-19 pandemic. Data from this large series suggest that a semisterile technique during CRPP of supracondylar humeral fractures is a safe practice. We anticipate that this could preserve approximately 20,000 gowns and masks in the United States over the next year. Physicians are encouraged to reevaluate their daily practice to identify safe opportunities for resource preservation.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Supracondylar humeral fractures represent one of the most common orthopaedic injuries in pediatric patients, representing 16.6% of fractures with an annual incidence of between 60.3 and 71.8 per 100,000[1-3]. Although the majority of these fractures are nondisplaced and amenable to cast immobilization, approximately 24% will require operative fixation[2]. Furthermore, nearly 90% of surgically indicated fractures will undergo closed reduction and percutaneous pinning (CRPP), and approximately 10% will need to be treated with an open surgical procedure[2]. Given that CRPP is a relatively brief, minimally invasive procedure, the complication profile is reported as favorable[4-6].

Although pin-track infections do occur[7,8], deep infections are rare following CRPP of supracondylar humeral fractures, prompting a growing interest in a semisterile surgical preparation technique for this procedure[8-10]. In a review of 304 patients, Iobst et al. reported no postoperative infections using a semisterile technique, despite 68% of their patients not receiving perioperative antibiotics[8]. A systematic review by the same authors reported an overall infection rate of 2.34% with a deep infection rate of 0.47% (9 of 1,922 patients included in their review)[8]. Their published technique is performed in the operating room with sterile towel isolation of the surgical field (rather than draping) and the use of sterile gloves[8-10]. Proponents of the semisterile technique cite resource stewardship and time savings as benefits of the technique and report no added risk to the patient.

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Fig. 1

Preparation example showing the semisterile technique used at our institution and as previously described[8,9].

Recent global events with the COVID-19 pandemic have quickly strained the supply of personal protective equipment (PPE), and, thus, even small conservation measures are welcomed by our health-care system. Our center has targeted opportunities to conserve PPE with a focus on masks and gowns. Although operative schedules at most institutions have been skeletonized, in part to preserve resources, urgent cases, such as CRPP of supracondylar humeral fractures, remain essential. PPE shortages are reaching critical levels in some areas, and this has stimulated a plea for ideas from prominent voices within medicine[11].

With the rapid depletion of PPE, resource utilization throughout every health-care system should be scrutinized closely. Given the percutaneous nature of CRPP of supracondylar humeral fractures, we expect the risk to be small, even without gown use. Therefore, limiting PPE use where safe for both patient and physician should be prioritized. The purpose of this study was to assess the efficacy and safety for both surgeons and patients of 2 variations of semisterile (henceforth defined as without gowns or traditional surgical drapes) CRPP of supracondylar humeral fractures.

Materials and Methods

This study is an institutional review board-approved retrospective chart review of patients presenting to 1 of 2 large, metropolitan, pediatric hospitals within the same hospital system. Codes from the International Classification of Diseases, Ninth Revision (ICD-9), were used to query the institutional database to identify patients with a supracondylar humeral fracture. We used ICD-9 code 812.41 and corresponding ICD, Tenth Revision (ICD-10) codes to identify a consecutive series of patients who presented to the emergency department with a closed supracondylar humeral fracture. During our study period, from 2012 to February 2020, 1,343 (50.4%) of 2,665 patients underwent operative fixation of supracondylar humeral fractures.

We reviewed each patient undergoing surgical fixation of an isolated supracondylar humeral fracture. Patients with open fractures, those requiring an open approach (i.e., for vascular injury or to achieve acceptable reduction), and patients with other injuries were excluded from analysis (73 patients [5.4%]). This left 1,270 patients for the final analysis. Each fracture was graded by a senior-level resident according to the modified Gartland classification system[12] as either Type-II or Type-III fractures (Type-I fractures were universally managed nonoperatively)[7]. Each patient's age, sex, hospital length of stay, hospital month of admission, and infectious complications were recorded. Both deep infections (i.e., subperiosteal abscess, osteomyelitis, and/or need for long-term antibiotics [>7 days]) and pin-track infections were recorded. For the purposes of this study, we defined clinically relevant pin-track infections as requiring early pin removal, return to the operating room, and/or oral antibiotics (i.e., any possible superficial pin-track infection that improved with routine hygiene or did not require formal treatment [e.g., antibiotics] was not included). Last, each included faculty member was surveyed for any bodily fluid occupational exposures that occurred perioperatively.

Of the 10 surgeons performing CRPP of supracondylar humeral fractures, 3 used a semisterile technique (the patients who underwent this procedure were referred to as the semisterile group), and the other 7 used traditional full preparation and draping (the patients who underwent this procedure were referred to as the sterile group). Additionally, 1 surgeon (D.P.D.) in the

Fig. 2

Photograph showing a traditional full sterile preparation and draping setup for CRPP of a supracondylar humeral fracture.

semisterile group performed these procedures without a mask, and we therefore chose to further analyze patients who had the procedure with and without a masked surgeon. In brief, the semisterile technique involves using 3 or 4 sterile towels to isolate and prepare only the exposed elbow after reduction is confirmed on fluoroscopy, prior to draping or toweling. An iodine povacrylex and isopropanol surgical antiseptic applicator (DuraPrep; 3M) is then used to sterilize the area of interest. Sterile gloves are worn, but a surgical gown is not (Fig. 1). If anatomic reduction is not obtained and an open procedure is needed, conversion to a full sterile preparation can easily be performed prior to any cutaneous incision. Pins are then inserted percutaneously in the routine fashion. The procedure may be performed by a single surgeon or with an assistant using sterile gloves. The sterile cohort was cared for by 7 surgeons using a traditional operating room setup with surgical drapes and the surgeon gowned, gloved, and masked (Fig. 2). All other elements of care were standardized, and all patients received a single dose of preoperative intravenous antibiotics.

Cost analysis was performed using published supracondylar humeral fracture incidence estimations[2,3] in conjunction with U.S. Census Bureau data[13] to estimate annual CRPP procedural incidence in the United States. The institutional costs of a standard extremity drape pack ($94), gowns ($2 per gown), and face masks (approximately $0.10 per mask) were then obtained and were used to estimate potential cost savings on a national basis. We conservatively accounted for a savings of 1 drape, 2 gowns, and 2 masks per case (surgical technician and surgeon). Therefore, savings of $98.20 per case and associated PPE preservation could be expected by utilizing a semisterile technique. Additionally, we used data from the literature to roughly estimate savings associated with decreased operating room time using the semisterile technique, which is known to be 10 minutes[9]. The cost per minute of operating room time was estimated conservatively at $30 based on prior literature[14].

Descriptive statistics and chi-square univariate analysis were performed to examine for any possible differences between cohorts. Regression analysis could not be performed on infectious complications as the incidence of infection was 0 in 1 group. Significance was set at $p < 0.05$ for the purposes of this study. All statistical analysis was performed using SPSS version 25 (IBM).

Results

Patient Characteristics

Of 1,270 patients, 396 (31.2%) were treated with a semisterile technique and 158 (12.4%) were treated by a surgeon who did not wear a mask. There were no differences between the groups in age, sex, and length of stay after admission. Patients had a mean age of 6 years, and sex approached an even divide between male patients and female patients. Over 90% of patients stayed in the hospital <24 hours. The proportion of fracture occurrence and treatment for the entire cohort was greatest in April to June (30.2%), followed by July to September (27.0%), October to December (25.3%), and January to March (17.5%) (Table I).

Sterile Technique Compared with Semisterile Technique and Infectious Complications

In this study, 396 patients (31.2%) were treated using the semisterile technique and 874 patients (68.8%) were treated using the sterile technique. As noted, all 3 deep infections occurred in the sterile preparation group. No infectious complications occurred in this series with the semisterile technique. There were no differences in patient age, sex, length of stay, or fracture type between groups ($p > 0.2$ for all comparisons). The semisterile group had fewer patients treated in April to June ($p = 0.004$) (Table I).

Mask Compared with No Mask and Infectious Complications

Patients who underwent CRPP by a surgeon without a mask more commonly had a Gartland Type-III supracondylar humeral fracture (73.4% compared with 63.8%; $p = 0.018$). There were no

TABLE I Characteristics of Patient Cohorts and Infectious Outcomes

Characteristic	Sterile	Semisterile	P Value
Total*	874 (68.8%)	396 (31.2%)	
Age group*			0.559
<5 yr	341 (39.0%)	148 (37.4%)	
5 to 9 yr	486 (55.6%)	221 (55.8%)	
≥10 yr	47 (5.4%)	27 (6.8%)	
Age† *(yr)*	5.7 ± 2.4	5.9 ± 2.5	0.221
Sex*			0.333
Female	418 (47.8%)	201 (50.8%)	
Male	456 (52.2%)	195 (49.2%)	
Length of stay*			0.345
<1 day	800 (91.5%)	356 (89.9%)	
≥1 day	74 (8.5%)	40 (10.1%)	
Fracture classification*			0.283
Type II	314 (35.9%)	130 (32.8%)	
Type III	560 (64.1%)	266 (67.2%)	
Month of admission*			0.004
January to March	149 (17.0%)	73 (18.4%)	
April to June	291 (33.3%)	93 (23.5%)	
July to September	228 (26.1%)	115 (29.0%)	
October to December	206 (23.6%)	115 (29.0%)	
Infectious complications*			
Deep infection	3 (0.34%)	0 (0%)	0.556
Pin-track infection†	0 (0%)	0 (0%)	0.999

*The values are given as the number of patients, with the percentage in parentheses. †The values are given as the mean and the standard deviation. ‡This includes only pin-track infections requiring early pin removal, return to the operating room, and/or oral antibiotics.

clinically relevant pin-track infections in either group (p = 0.999). Three patients in the sterile and masked group and no patients in the maskless group sustained a deep surgical infection (p = 0.999). Each patient who developed an infection required a return to the operating room and intravenous, followed by oral, antibiotics (Table II). One patient required multiple irrigation and debridements.

Infectious Complications and Occupational Exposures

On closer examination of the 3 cases of deep infection (0.24%), all occurred in patients <5 years of age (p = 0.091), two-thirds of the patients were male (p = 0.999), and all occurred in patients who were admitted under observation status (p = 0.893) and stayed for <1 day (p = 0.999). Additionally, two-thirds of cases were Type-III fractures (p = 0.999), and all occurred with different seasonal temporality (p = 0.883). All infections occurred in the sterile and masked group (Table III). There were no surgeon-reported occupational exposures in either group.

TABLE II Characteristics of Patients and Infectious Outcomes: Mask Compared with No Mask

Characteristic	Mask	No Mask	P Value
Total*	1,112 (87.6%)	158 (12.4%)	
Age group*			0.869
<5 yr	431 (38.8%)	58 (36.7%)	
5 to 9 yr	617 (55.5%)	90 (57.0%)	
≥10 yr	64 (5.8%)	10 (6.3%)	
Age† *(yr)*	5.8 ± 2.5	6.0 ± 2.4	0.818
Sex*			0.866
Female	541 (48.7%)	78 (49.4%)	
Male	571 (51.3%)	80 (50.6%)	
Length of stay*			0.957
<1 day	1,012 (91.0%)	144 (91.1%)	
≥1 day	100 (9.0%)	14 (8.9%)	
Fracture classification*			0.018
Type II	402 (36.2%)	42 (26.6%)	
Type III	710 (63.8%)	116 (73.4%)	
Month of admission*			0.009
January to March	189 (17.0%)	33 (20.9%)	
April to June	351 (31.6%)	33 (20.9%)	
July to September	304 (27.3%)	39 (24.7%)	
October to December	268 (24.1%)	53 (33.5%)	
Infectious complications*			
Deep infection	3 (0.27%)	0 (0%)	0.999
Pin-track infection‡	0 (0%)	0 (0%)	0.999

*The values are given as the number of patients, with the percentage in parentheses. †The values are given as the mean and the standard deviation. ‡This includes only pin-track infections requiring early pin removal and/or return to the operating room.

Estimation of Cost and PPE Savings with National Adoption of the Semisterile Technique

Using the most recent population data available in conjunction with incidence data from Holt et al.[2,3], we calculated that 9,306 to 11,081 patients undergo CRPP of a supracondylar humeral fracture annually in the United States. Assuming that all providers are using a full sterile technique, conversion to a semisterile technique could result in substantial cost savings. Using our cost data, financial savings from only drapes, gown, and masks equates to annual hospital cost savings of between $913,849 and $1,088,154. When considering the 10 minutes of operating room time savings per case[9], an additional savings of $300 per case would be expected[14]. Extrapolated to the national volume of CRPP of supracondylar humeral fractures, this could save $2.8 million to $3.3 million annually. Summative, annual savings of between $3.7 million and $4.4 million could therefore be expected in the United States. Additionally, national adoption of this technique could account for important PPE preservation including (conservatively) between 18,612 and 22,162 gowns and masks annually in the United States, for this procedure alone.

Discussion

Supracondylar humeral fractures are the most common pediatric fracture about the elbow[3]. Although the majority of patients can be managed with cast immobilization, approximately 24% ultimately require operative intervention, and the majority of these involve CRPP[2,3]. In the current medical climate, balancing risk mitigation and cost containment is increasingly essential. There have been 2 series from the United States that have shown the use of a semisterile technique for CRPP of supracondylar humeral fractures, and both studies have shown favorable outcomes with the technique, with the potential for financial and resource savings[8,9]. Our current series is the largest known to date and is less subject to confounders—for example, because of standardized preoperative administration of antibiotics[8]. Our study additionally examines the safety of the semisterile technique and the potential financial and PPE benefits on a more granular level.

We found no significant difference in infectious complications between sterile and semisterile preparation techniques or between unmasked and masked procedures. Our results with regard to full sterile preparation and draping agree with prior investigations[8-10], and there are now 1,572 cases in the literature using the semisterile technique with no reported deep infections. We additionally utilized previously published data in conjunction with institutional cost data to estimate cost and resource savings with national adoption of the semisterile technique. This analysis estimates that approximately 20,000 surgical gowns and masks could be saved per year and cost savings of around $4 million annually could be expected.

Further, gown and face mask preservation is safe for patients. Prior literature on departures from classical orthopaedic sterility

measures (multilayered surgical draping and perioperative antibiotics) has suggested that this does not impact the baseline infection risk[7,8,15] in CRPP of supracondylar humeral fractures[8,9]. Further, even the rare pin-track infection that occurs regardless of adherence to traditional sterility measures is typically of limited clinical importance, often resolving with only daily hygiene[15-18]. These data have been extrapolated and applied to adult percutaneous skeletal fixation of hand fractures, with equally promising results and cost savings using the semisterile technique[9,19]. As such, these findings speak to the relative safety of closed reduction and percutaneous skeletal fixation procedures.

When considered on a larger scope, our findings are predictable. Many bedside procedures, such as suture repair of traumatic lacerations, application of skeletal or cervical traction, or joint aspiration or injection, are frequently performed without the use of a mask or full sterile preparation. Under typical circumstances, the cost of perfunctory use of full preparation with gowns and drapes for CRPP of supracondylar humeral fractures (or any of these bedside procedures) is not inconsequential, but, in the pandemic landscape, this may unnecessarily burden a system desperate for PPE to protect health-care providers treating a virulent infectious agent[11,20,21].

The results of this study largely agree with prior literature published on the semisterile technique[8-10]. Although a large series was published by a group from Turkey, that study had no comparison group and the procedures were performed predominantly by trainees[10]. That group also reported atypically high complication rates (7.3% pin-track infections, 8.3% iatrogenic nerve injury, and 11.5% loss of reduction), despite no deep infections[10]. Therefore, our contemporary, large, single-institution series clarifies the remaining gaps from the prior literature and expands on the potential for cost savings and resource preservation. Given the existing series, it seems that the semisterile technique is safe and could save millions of dollars annually. Importantly, this is also an opportunity for PPE resource preservation under normal circumstances. A nationwide adoption of this policy will diminish costs and enable resource reallocation. Despite our findings, surgeons should still strictly adhere to the U.S. Centers for Disease Control and Prevention (CDC) regulations of self-protection in the operating room, as this study was conducted during nonpandemic times[22].

Although our study has multiple strengths, there were also weaknesses that must be addressed. First, given the retrospective nature of this study, causality could not be determined. Second, the rate of deep infection following CRPP of a supracondylar humeral fracture was exceedingly low[8]. To be sufficiently powered to detect even a doubling of the infection rate between cohorts (with an infection rate of 0.47%), nearly 5,000 patients per group would be required. Although our series is, to our knowledge, the largest reported on the subject from the United States and our zero infections in the semisterile cohort is reassuring, this study should serve as the impetus for a larger, multi-institution study powered to detect differences in infectious outcomes. Third, we excluded fractures managed nonoperatively. The potential benefits of CRPP for Type-II fractures, especially those without medial comminution, should be carefully assessed and cautiously weighed against the risk of operative intervention. Our belief is that many less-displaced Type-II fractures may be successfully managed with closed treatment while more-displaced fractures should undergo CRPP to prevent malunion[7,23]. Additionally, our cost estimates are based on institutional data, which may limit external validity. To improve generalizability, we used estimated, per minute, operating room costs[24] and favored conservative estimates[14]. Further, foregoing mask wear would be contrary to the CDC recommendations[25] during pandemic situations and is therefore not recommended at this time. Although children seem to have a low risk of severe symptomatic disease, they can be asymptomatic carriers of the novel coronavirus severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which causes COVID-19, and our data do not permit definitively commenting on the safety of the surgeon when foregoing PPE during the COVID-19 era[26]. However, the reduction of surgeon PPE does not appear

TABLE III Characteristics of Patients Experiencing Deep Infection

Characteristic	Infection*	P Value
Operative sterility		0.243
Sterile	3 (0.34%)	
Semisterile	0 (0%)	
Operative mask status		0.999
Mask	3 (0.27%)	
No mask	0 (0%)	
Age group		0.091
<5 yr	3 (0.61%)	
5 to 9 yr	0 (0%)	
≥10 yr	0 (0%)	
Sex		0.999
Female	1 (0.16%)	
Male	2 (0.31%)	
Length of stay		0.999
<1 day	3 (0.26%)	
≥1 day	0 (0%)	
Fracture classification		0.999
Type II	1 (0.23%)	
Type III	2 (0.24%)	
Month		0.883
January to March	0 (0%)	
April to June	1 (0.26%)	
July to September	1 (0.29%)	
October to December	1 (0.31%)	

*The values are given as the number of patients, with the percentage in parentheses.

to increase postoperative infections. Lastly, exposure data in this series were self-reported, which is known to be subject to bias[27].

In conclusion, the semisterile technique represents a safe technique for CRPP of supracondylar humeral fractures. This study highlights the fact that an arbitrary approach to sterility may need reevaluation during these unique times. As previously noted, the CDC recommends surgical mask use. However, surgeons should reevaluate whether gowns are necessary for all procedures. Although surgical gowns are not traditionally used as frontline PPE, unprecedented shortages have necessitated creative, if not questionable, measures to protect vulnerable providers, and we hope that the reallocations proposed in this study both contribute to our health-care system and stimulate further efforts. In the long term, the semisterile technique affords resource stewardship and portends substantial national cost savings. Given these advantages of the semisterile technique, without obvious associated patient risk, we advocate for adoption of the semisterile technique for CRPP of supracondylar humeral fractures, especially during current relief efforts. We encourage others to closely review their procedures to look for similar opportunities to identify areas where conservation efforts could lessen the burden on the health-care system now and in the future. ■

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