Operative Experience During Orthopaedic Residency Compared with Early Practice in the U.S.

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Background: The goal of surgical education is to prepare the trainee for independent practice; however, the relevance of the current residency experience to practice remains uncertain. The purpose of this study was to identify the surgical procedures most frequently performed in orthopaedic residency and in early surgical practice and to identify surgical procedures performed more often or less often in orthopaedic residency compared with early surgical practice.

Methods: This retrospective cohort study included American Medical Association (AMA) Current Procedural Terminology (CPT) codes ($n = 4,329,561$ procedures) reported by all U.S. orthopaedic surgery residents completing residency between 2010 and 2012 ($n = 1,978$) and AMA CPT codes for all procedures ($n = 413,370$) reported by U.S. orthopaedic surgeons who took the American Board of Orthopaedic Surgery Part II certifying examination between 2013 and 2015 ($n = 2,205$). Relative rates were determined for AMA CPT codes and AMA CPT code categories for adult and pediatric surgeries that had frequencies of $\geq 0.1\%$ for both practitioners and residents.

Results: The top 25 adult AMA CPT code categories contributed 82.1% of the total case volume for residents and 82.4% for practitioners. Knee and shoulder arthroscopy were the most frequently performed procedures in adults in both residency and early practice. Humerus/elbow fracture and/or dislocation procedures and “other musculoskeletal—introduction or removal” procedures were the most frequently performed procedures in pediatric cases in both residency and early practice. Of the total 78 adult and 82 pediatric code categories included in our analysis that had a frequency of $>1\%$ in residency or early practice, there were 4 adult and 6 pediatric code categories demonstrating 44% to 1,164% greater frequency in residency than in early practice, and there were 8 adult and 7 pediatric code categories demonstrating 26% to 73% less frequency in residency than in early practice.

Conclusions: Similarity between residency and early practice experience is generally strong. However, we identified several AMA CPT code categories and individual CPT codes for which the level of exposure during residency varied substantially from early practice experience. These findings can help residencies ensure adequate trainee exposure to procedures performed commonly in early practice.

In the U.S., orthopaedic surgery residents currently are required to complete a 5-year training program under the guidelines of the Accreditation Council for Graduate Medical Education (ACGME)¹. Surgical residents must log every case they perform in an electronic data system. The Residency Review Committee (RRC) for Orthopaedic Surgery under the ACGME requires programs to provide residents a minimum number of cases in 15 categories as well as sets goals for the overall total number of cases that should be logged during the 5-year training program¹⁻³. To our knowledge, there

has been no report on the types of operative procedures to which orthopaedic residents are exposed during training or information on the frequency of surgical procedures residents perform versus those they perform early in their careers. The overall goal of the current study was to investigate the relevance of the current orthopaedic residency surgical experience to the operative procedures performed in early practice.

Our specific aims were to (1) identify the procedures performed most frequently in orthopaedic residency and in early orthopaedic practice and (2) identify procedures performed

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more often or less often in residency training compared with early practice.

Materials and Methods

Data Sources and Study Cohort

This was a retrospective cohort study using data from 2 sources: the ACGME and the American Board of Orthopaedic Surgery (ABOS) (Table I). The institutional review board determined that this study met the criteria for exemption.

The RRC requires all orthopaedic surgery residents to report their operative experience. Since 2002, all residents have entered cases on an Internet-based ACGME reporting system. The cases are recorded according to the American Medical Association (AMA) Current Procedural Terminology (CPT) codes and are then aggregated into 116 operation types in 15 clinical areas using a taxonomy devised by the RRC. The ACGME provided the AMA CPT codes entered by all U.S. orthopaedic surgery residents who graduated between 2010 and 2012 for all cases performed during their 5-year training programs, subclassified by adult and pediatric cases. These 1,978 residents reported participating in a total of 4,329,561 procedures consisting of 3,377 distinct AMA CPT codes. As our interest was in surgical cases, we excluded AMA CPT codes with “closed treatment” and/or “closed reduction” in the description.

We obtained the de-identified ABOS case lists of all practicing U.S. orthopaedic surgeons who took the Part II certifying examination between 2013 and 2015. We chose these years to maximize the number of same surgeons included in both cohorts, as 81% of 2013 to 2015 Part II candidates (1,785 of 2,205) graduated from U.S. orthopaedic residency training programs in 2010 to 2012. During the case collection period for the 2013 to 2015 ABOS Part II certifying examination, the

candidates performed 264,387 unique cases involving 413,370 total AMA CPT codes, of which 1,952 were distinct codes.

The individual CPT codes were categorized by the system of the AMA CPT codebook⁴. A total of 3,479 unique AMA CPT codes were in the combined datasets. Any AMA CPT code that had <10 cases reported by residents or practitioners was excluded from the analysis. Similarly, AMA CPT codes listed as “other procedures” were excluded from the analysis, as we were unable to identify the specific procedure. The AMA CPT codes were then collapsed by anatomical area and general class of surgery per the AMA CPT classification system for data analysis of these “code categories.” The major AMA CPT code domains were Surgery/Integumentary System, Surgery/Musculoskeletal System, and Surgery/Nervous System-Spine and Spinal Cord. Data were then subdivided by adult patients and pediatric patients (age of <18 years). AMA CPT code categories in the adult and pediatric datasets that had frequencies of <0.1% for both practitioners and residents were excluded from the analysis.

Data Analysis

The “Practitioner %” and “Resident %” rates for a particular AMA CPT code category were calculated via case frequency. For example, the Practitioner % for a particular AMA CPT code category was calculated by dividing the number of procedures performed by providers for that AMA CPT code category by the total number of procedures performed by providers across all AMA CPT code categories.

Relative rates were calculated for each AMA CPT code category according to the following formula: Resident %/Practitioner %. A relative rate of <1 indicates that resident exposure for that AMA CPT code or CPT code category was less than in practice, a relative rate of 1 indicates that resident exposure for that AMA CPT code or CPT code category was

TABLE I Summary of RRC Resident Data and ABOS Part II Certifying Practitioner Datasets

	Residents (2010-2012)	Practitioners (2013-2015)	Combined
Surgeons (no.)	1,978	2,205	—
Procedures (no.)	4,329,561	413,370	4,742,931
Adult patients	3,640,893	370,607	4,011,500
Pediatric patients	688,668	42,763	731,431
Individual CPT codes (no.)	3,377	1,952	3,479
Adult patients	3,165	1,876	3,273
Pediatric patients	2,418	1,327	2,475
Individual CPT codes included in analysis* (no.)	1,356	1,292	1,364
Adult patients	1,298	1,222	1,307
Pediatric patients	1,273	984	1,293
CPT code categories included in analysis† (no.)	88	88	88
Adult patients	78	78	78
Pediatric patients	82	82	82

*Any CPT codes that had ≥ 10 cases reported by residents or practitioners. †Grouped by anatomical area and general class of surgery per the AMA CPT classification system; included were code categories that represented $\geq 0.1\%$ of overall case volume for residents or practitioners.

equal to exposure in practice, and a relative rate of >1 indicates that resident exposure for that AMA CPT code or CPT code category was greater than in practice.

Relative rates for the adult and pediatric datasets were summarized by range, median, and interquartile range. We report on procedure categories that fell into the bottom quartile (<25 th percentile), middle quartiles (25th to 75th), and top quartile (>75 th). We identified AMA CPT code categories within each quartile that had a frequency of $>1\%$ for both residents and practitioners, and we also identified the most common individual AMA CPT codes for residents and practitioners. AMA CPT code categories with a frequency of $>1\%$ and a relative rate in the bottom quartile were identified as procedures performed more commonly in practice than in residency. Similarly, AMA CPT code categories with a frequency of $>1\%$ and a relative rate in the top quartile indicated procedures that were performed more commonly in residency than in practice.

Results

The initial set of 3,479 unique AMA CPT codes was reduced to 88 AMA CPT code categories. After exclusion criteria were applied, 78 code categories were included in the adult dataset, and 82 code categories were included in the pediatric dataset. Of the total resident case volume, 84.1% (3,640,893 of 4,329,561) were adult cases and 15.9% (688,668 of 4,329,561) were pediatric cases. Of the total case volume for early practitioners, 89.7% (370,607 of 413,370) were adult cases and 10.3% (42,763 of 413,370) were pediatric cases (Table I).

Top AMA CPT Code Categories in Residency and Early Practice

Tables II and III show the top 25 AMA CPT code categories to which residents and early practitioners were exposed in the treatment of adult patients. "Femur/knee arthroscopy" was the

TABLE II Summary of Top 25 Adult AMA CPT Code Categories, Sorted by Resident Case Frequency

Rank	Adult AMA CPT Code Category	Practitioner %	Resident %*	Relative Rate
1	Femur/knee arthroscopy	9.09	10.57	1.16
2	Femur/knee repair, revision, and/or reconstruction	5.01	8.52	1.70
3	Shoulder arthroscopy	9.35	6.94	0.74
4	Pelvis/hip repair, revision, and/or reconstruction	3.91	5.81	1.49
5	Other musculoskeletal – introduction or removal	5.46	5.48	1.00
6	Leg/ankle trauma - fracture and/or dislocation	4.99	5.31	1.06
7	Integumentary system - incision/excision	4.70	4.34	0.92
8	Pelvis/hip trauma - fracture and/or dislocation	6.10	4.10	0.67
9	Femur/knee trauma - fracture and/or dislocation	2.20	3.17	1.44
10	Nervous system spine and spinal cord neuroplasty	4.25	2.80	0.66
11	Forearm/wrist fracture and/or dislocation	3.14	2.57	0.82
12	Shoulder repair, revision, and/or reconstruction	2.29	2.35	1.03
13	Spine arthrodesis/posterior	1.63	2.24	1.37
14	Nervous system spine and spinal cord posterior extradural laminotomy or laminectomy for exploration/decompression of neural elements or excision of herniated intervertebral disc	2.99	2.21	0.74
15	Foot/toes repair, revision, and/or reconstruction	1.21	1.85	1.52
16	Spine instrumentation	2.69	1.76	0.65
17	Leg/ankle repair, revision, and/or reconstruction	1.67	1.71	1.02
18	Hand/fingers incision	1.99	1.65	0.83
19	Hand/fingers repair, revision, and/or reconstruction	1.54	1.60	1.04
20	Humerus/elbow fracture and/or dislocation	1.37	1.54	1.12
21	Hand/fingers fracture and/or dislocation	1.76	1.34	0.76
22	Foot/toes trauma - fracture and/or dislocation	0.96	1.20	1.25
23	Forearm/wrist repair, revision, and/or reconstruction	0.96	1.14	1.19
24	Shoulder fracture and/or dislocation	1.40	1.02	0.73
25	Hand/fingers excision	1.20	0.90	0.75
Summary statistics†		81.9	82.1	1.03

*Sorted by this column. †The values are given as the sum for the Practitioner % and Resident % columns and as the average for the Relative Rate column.

TABLE III Summary of Top 25 Adult AMA CPT Code Categories, Sorted by Practitioner Case Frequency

Rank	Adult AMA CPT Code Category	Practitioner %*	Resident %	Relative Rate
1	Shoulder arthroscopy	9.35	6.94	0.74
2	Femur/knee arthroscopy	9.09	10.57	1.16
3	Pelvis/hip trauma - fracture and/or dislocation	6.10	4.10	0.67
4	Other musculoskeletal – introduction or removal	5.46	5.48	1.00
5	Femur/knee repair, revision, and/or reconstruction	5.01	8.52	1.70
6	Leg/ankle trauma - fracture and/or dislocation	4.99	5.31	1.06
7	Integumentary system - incision/excision	4.70	4.34	0.92
8	Nervous system spine and spinal cord neuroplasty	4.25	2.80	0.66
9	Pelvis/hip repair, revision, and/or reconstruction	3.91	5.81	1.49
10	Forearm/wrist fracture and/or dislocation	3.14	2.57	0.82
11	Nervous system spine and spinal cord posterior extradural laminotomy or laminectomy for exploration/decompression of neural elements or excision of herniated intervertebral disc	2.99	2.21	0.74
12	Spine instrumentation	2.69	1.76	0.65
13	Shoulder repair, revision, and/or reconstruction	2.29	2.35	1.03
14	Femur/knee trauma - fracture and/or dislocation	2.20	3.17	1.44
15	Hand/fingers incision	1.99	1.65	0.83
16	Hand/fingers fracture and/or dislocation	1.76	1.34	0.76
17	Leg/ankle repair, revision, and/or reconstruction	1.67	1.71	1.02
18	Spine arthrodesis/posterior	1.63	2.24	1.37
19	Hand/fingers repair, revision, and/or reconstruction	1.54	1.60	1.04
20	Shoulder fracture and/or dislocation	1.40	1.02	0.73
21	Spine arthrodesis/anterior	1.40	0.89	0.63
22	Humerus/elbow fracture and/or dislocation	1.37	1.54	1.12
23	Foot/toes repair, revision, and/or reconstruction	1.21	1.85	1.52
24	Hand/fingers excision	1.20	0.90	0.75
25	Humerus/elbow repair, revision, and/or reconstruction	1.04	0.80	0.77
Summary statistics†		82.4	81.5	0.98

*Sorted by this column. †The values are given as the sum for the Practitioner % and Resident % columns and as the average for the Relative Rate column.

AMA CPT code category with the greatest frequency in residency (10.57%). The relative rate of “femur/knee arthroscopy” was 1.16, indicating that procedures in this category were performed 16% more frequently by residents than by practicing orthopaedic surgeons (frequency of 9.09%). Among practitioners, “shoulder arthroscopy” was the AMA CPT code category with the greatest frequency in the treatment of adult patients (9.35%). The relative rate was 0.74, indicating that residents performed procedures in this category 26% less frequently than did practitioners.

The top 10 AMA CPT code categories constituted 57.0% of the adult surgical case volume for residents and 56.0% of the adult surgical case volume for practitioners.

Tables IV and V show the top 25 AMA CPT code categories to which residents and early practitioners were

exposed in the treatment of pediatric patients. The category with the greatest frequency in residency was “other musculoskeletal–introduction or removal” (9.21%). The relative rate was 1.10, indicating that residents performed procedures in this category slightly more frequently than did practitioners. Among practitioners, “femur/knee arthroscopy” was the AMA CPT code category with the greatest frequency in the treatment of pediatric patients (13.89%). The relative rate was 0.42, indicating that residents performed procedures this category 58% less frequently than did practitioners, although it was still the fifth-most-common AMA CPT code category among residents (at 5.89%).

The top 10 AMA CPT code categories constituted 55.7% of the pediatric surgical case volume for residents and 62.7% of the pediatric surgical case volume for practitioners.

TABLE IV Summary of Top 25 Pediatric AMA CPT Code Categories, Sorted by Resident Case Frequency

Rank	Pediatric AMA CPT Code Category	Practitioner %	Resident %*	Relative Rate
1	Other musculoskeletal - introduction or removal	8.37	9.21	1.10
2	Humerus/elbow fracture and/or dislocation	11.80	8.18	0.69
3	Femur/knee repair, revision, and/or reconstruction	3.08	6.16	2.00
4	Leg/ankle repair, revision, and/or reconstruction	2.20	6.16	2.80
5	Femur/knee arthroscopy	13.89	5.89	0.42
6	Foot/toes repair, revision, and/or reconstruction	1.95	5.27	2.70
7	Pelvis/hip repair, revision, and/or reconstruction	1.99	4.37	2.19
8	Spine instrumentation	1.34	4.23	3.16
9	Leg/ankle incision	1.72	3.19	1.85
10	Integumentary system - incision/excision	5.56	3.05	0.55
11	Femur/knee trauma - fracture and/or dislocation	2.75	3.02	1.10
12	Spine arthrodesis/deformity	1.05	2.99	2.84
13	Leg/ankle trauma - fracture and/or dislocation	4.88	2.85	0.58
14	Pelvis/hip incision	1.15	2.68	2.33
15	Forearm/wrist fracture and/or dislocation	5.79	2.37	0.41
16	Hand/fingers repair, revision, and/or reconstruction	2.20	2.12	0.96
17	Spine arthrodesis/posterior	0.16	2.03	12.64
18	Pelvis/hip trauma - fracture and/or dislocation	1.12	1.56	1.39
19	Spine osteotomy	0.49	1.25	2.55
20	Hand/fingers fracture and/or dislocation	4.35	1.16	0.27
21	Forearm/wrist repair, revision, and/or reconstruction	1.07	1.14	1.07
22	Femur/knee excision	0.93	1.12	1.20
23	Foot/toes excision	0.65	1.12	1.71
24	Pelvis/hip introduction or removal	0.80	1.09	1.36
25	Femur/knee incision	0.87	1.06	1.21
Summary statistics†		80.2	83.3	1.96

*Sorted by this column. †The values are given as the sum for the Practitioner % and Resident % columns and as the average for the Relative Rate column.

AMA CPT Code Categories with Lesser and Greater Frequency in Residency Than in Early Practice

The relative rates of the AMA CPT code categories for adult cases ranged from 0.12 to 4.41, with a median value of 1.08. (Table VI). Of the 19 AMA CPT code categories in the bottom relative-rate quartile of adult cases, 8 had a frequency of >1% among practitioners (Table VI, bottom quartile). These 8 code categories had relative rates of 0.63 to 0.74, indicating that procedures in these categories were performed 26% to 37% less frequently in residency than in early practice. Of the AMA CPT code categories in the top relative-rate quartile of adult cases, 4 had a frequency of >1% among residents (Table VI, top quartile). These 4 code categories had relative rates of 1.44 to 1.70, indicating that procedures in these categories were performed 44% to 70% more frequently in residency than in early practice.

The pediatric AMA CPT code category data show a wider distribution of relative rates (0.18 to 14.00), with a median value of 1.10 (Table VII). Of the 21 AMA CPT code categories

in the bottom relative-rate quartile, 7 had a frequency of >1% among practitioners (Table VII, bottom quartile). These 7 code categories had relative rates of 0.27 to 0.55, indicating that procedures in these categories were performed 45% to 73% less frequently in residency than in early practice. There were 6 AMA CPT code categories in the top pediatric relative-rate quartile with a frequency of >1% among residents (Table VII, top quartile). These 6 had relative rates of 2.55 to 12.64, indicating that procedures in these categories were performed 155% to 1,164% more frequently in residency than in early practice.

Top AMA CPT Codes, and Frequency Differences Between Practice and Residency

In addition to AMA CPT code categories, we also analyzed individual AMA CPT codes. The 25 most frequently performed orthopaedic adult procedures by AMA CPT code constituted >40% of the residents' and early practitioners' adult case

TABLE V Summary of Top 25 Pediatric AMA CPT Code Categories, Sorted by Practitioner Case Frequency

Rank	Pediatric AMA CPT Code Category	Practitioner %*	Resident %	Relative Rate
1	Femur/knee arthroscopy	13.89	5.89	0.42
2	Humerus/elbow fracture and/or dislocation	11.80	8.18	0.69
3	Other musculoskeletal - introduction or removal	8.37	9.21	1.10
4	Forearm/wrist fracture and/or dislocation	5.79	2.37	0.41
5	Integumentary system - incision/excision	5.56	3.05	0.55
6	Leg/ankle trauma - fracture and/or dislocation	4.88	2.85	0.58
7	Hand/fingers fracture and/or dislocation	4.35	1.16	0.27
8	Femur/knee repair, revision, and/or reconstruction	3.08	6.16	2.00
9	Femur/knee trauma - fracture and/or dislocation	2.75	3.02	1.10
10	Hand/fingers repair, revision, and/or reconstruction	2.20	2.12	0.96
11	Leg/ankle repair, revision, and/or reconstruction	2.20	6.16	2.80
12	Pelvis/hip repair, revision, and/or reconstruction	1.99	4.37	2.19
13	Foot/toes repair, revision, and/or reconstruction	1.95	5.27	2.70
14	Shoulder arthroscopy	1.77	0.76	0.43
15	Leg/ankle incision	1.72	3.19	1.85
16	Hand/fingers incision	1.41	1.03	0.73
17	Spine instrumentation	1.34	4.23	3.16
18	Shoulder fracture and/or dislocation	1.16	0.42	0.36
19	Pelvis/hip incision	1.15	2.68	2.33
20	Pelvis/hip trauma - fracture and/or dislocation	1.12	1.56	1.39
21	Forearm/wrist repair, revision, and/or reconstruction	1.07	1.14	1.07
22	Foot/toes trauma - fracture and/or dislocation	1.05	0.61	0.58
23	Spine arthrodesis/deformity	1.05	2.99	2.84
24	Forearm/wrist excision	1.02	0.55	0.54
25	Femur/knee excision	0.93	1.12	1.20
Summary statistics†		83.6	80.1	1.29

*Sorted by this column. †The values are given as the sum for the Practitioner % and Resident % columns and as the average for the Relative Rate column.

volumes (see Appendix Tables E-1 and E-2, respectively). Among residents, the most frequently performed procedure in adults was AMA CPT code 27447, “total knee arthroplasty,” which was performed almost twice as often in residency as in early practice (relative rate, 1.85). Among early practitioners, the most frequently performed procedure in adults was AMA CPT code 29881, “arthroscopy, knee, surgical; with meniscectomy...,” which was performed at nearly equal rates between early practice and residency (relative rate, 1.01).

The 25 most frequently performed orthopaedic pediatric procedures by AMA CPT code contributed to almost 35% of the residents’ pediatric case volume and 42% of the early practitioners’ pediatric case volume (see Appendix Tables E-3 and E-4, respectively). Residents were exposed to pediatric spinal deformity and instrumentation procedures 176% to 179% more frequently (relative rates of 2.76 to 2.79) than early practitioners. Residents were exposed to substantially (64% to 74%) fewer knee arthroscopic procedures (AMA CPT codes

29888, 29881, and 29882; relative rates of 0.36, 0.36, and 0.26, respectively) than were early practitioners (see Appendix Tables E-3 and E-4).

All AMA CPT codes included in the adult procedure analysis are shown in Appendix Table E-5, and AMA CPT codes included in the pediatric procedure analysis are shown in Appendix Table E-6.

Discussion

We performed a unique analysis of 2 de-identified datasets comparing orthopaedic operative experience during residency versus early practice in the U.S. We found that, for both residents and practitioners, the 25 most frequent AMA CPT code categories for adult and pediatric cases represented >80% of the total case volumes. As assessed by AMA CPT code categories for adult cases, knee and shoulder arthroscopy were the procedures most frequently performed in both residency and early practice. With respect to pediatric cases,

TABLE VI Index of All Adult AMA CPT Code Categories Used by Both Practitioners and Residents, Sorted by Relative-Rate Quartiles

	Practitioner %	Resident %	Relative Rate*
Bottom quartile of AMA CPT code categories by relative rate			
(1) Radiology diagnostic radiology radiographic guidance fluoroscopic guidance	0.10	0.01	0.12
(2) Integumentary system debridement	0.22	0.07	0.31
(3) Integumentary system introduction	0.63	0.20	0.32
(4) Pelvis/hip arthroscopy	0.78	0.28	0.36
(5) Foot/toes arthroscopy	0.24	0.09	0.39
(6) Integumentary system incision and drainage	0.74	0.31	0.42
(7) Other musculoskeletal other procedures	0.82	0.36	0.44
(8) Integumentary system repair - complex	0.57	0.28	0.49
(9) Spine arthrodesis/anterior†	1.40	0.89	0.63
(10) Spine instrumentation†	2.69	1.76	0.65
(11) Nervous system spine and spinal cord neuroplasty†	4.25	2.80	0.66
(12) Pelvis/hip trauma - fracture and/or dislocation†	6.10	4.10	0.67
(13) Forearm/wrist arthroscopy	0.77	0.52	0.68
(14) Integumentary system repair - simple	0.23	0.16	0.70
(15) Forearm/wrist excision†	1.01	0.73	0.73
(16) Shoulder fracture and/or dislocation†	1.40	1.02	0.73
(17) Forearm/wrist incision	0.55	0.40	0.74
(18) Nervous system spine and spinal cord posterior extradural laminotomy or laminectomy for exploration/decompression of neural elements or excision of herniated intervertebral disc†	2.99	2.21	0.74
(19) Shoulder arthroscopy†	9.35	6.94	0.74
Middle quartiles of AMA CPT code categories by relative rate			
(1) Hand/fingers excision	1.20	0.90	0.75
(2) Hand/fingers fracture and/or dislocation	1.76	1.34	0.76
(3) Humerus/elbow repair, revision, and/or reconstruction	1.04	0.80	0.77
(4) Forearm/wrist fracture and/or dislocation	3.14	2.57	0.82
(5) Hand/fingers incision	1.99	1.65	0.83
(6) Nervous system spine and spinal cord neurorrhaphy	0.34	0.28	0.84
(7) Hand/fingers amputation	0.42	0.38	0.91
(8) Integumentary system - incision/excision	4.70	4.34	0.92
(9) Humerus/elbow excision	0.35	0.34	0.97
(10) Shoulder manipulation	0.10	0.10	0.98
(11) Integumentary system repair-intermediate	0.25	0.24	0.99
(12) Other musculoskeletal - introduction or removal	5.46	5.48	1.00
(13) Leg/ankle arthroscopy	0.44	0.45	1.02
(14) Leg/ankle repair, revision, and/or reconstruction	1.67	1.71	1.02
(15) Shoulder incision	0.12	0.12	1.03
(16) Shoulder repair revision, and/or reconstruction	2.29	2.35	1.03
(17) Hand/fingers repair, revision, and/or reconstruction	1.54	1.60	1.04
(18) Integumentary system skin grafts	0.38	0.39	1.04
(19) Leg/ankle trauma - fracture and/or dislocation	4.99	5.31	1.06
(20) Femur/knee incision	0.58	0.63	1.08
(21) Humerus/elbow incision	0.19	0.21	1.08
(22) Femur/knee trauma - manipulation	0.24	0.26	1.11
(23) Humerus/elbow fracture and/or dislocation	1.37	1.54	1.12
(24) Other musculoskeletal repair, revision, or reconstruction	0.31	0.36	1.16

continued

TABLE VI (continued)

	Practitioner %	Resident %	Relative Rate*
(25) Femur/knee arthroscopy	9.09	10.57	1.16
(26) Foot/toes excision	0.57	0.65	1.16
(27) Foot/toes amputation	0.28	0.33	1.18
(28) Forearm/wrist repair, revision, and/or reconstruction	0.96	1.14	1.19
(29) Other musculoskeletal excision	0.19	0.23	1.20
(30) Foot/toes trauma - fracture and/or dislocation	0.96	1.20	1.25
(31) Pelvis/hip introduction or removal	0.16	0.21	1.29
(32) Pelvis/hip incision	0.28	0.38	1.35
(33) Leg/ankle excision	0.31	0.43	1.36
(34) Leg/ankle amputation	0.26	0.35	1.37
(35) Spine arthrodesis/posterior	1.63	2.24	1.37
(36) Hand/fingers arthrodesis	0.17	0.23	1.40
(37) Humerus/elbow arthroscopy	0.12	0.16	1.40
(38) Integumentary system flaps	0.08	0.11	1.40
Top quartile of AMA CPT code categories by relative rate			
(1) Foot/toes incision	0.20	0.28	1.43
(2) Shoulder excision	0.35	0.50	1.43
(3) Femur/knee trauma - fracture and/or dislocation†	2.20	3.17	1.44
(4) Leg/ankle incision	0.49	0.73	1.49
(5) Pelvis/hip repair, revision, and/or reconstruction‡	3.91	5.81	1.49
(6) Foot/toes repair, revision, and/or reconstruction‡	1.21	1.85	1.52
(7) Femur/knee excision	0.42	0.72	1.70
(8) Femur/knee repair, revision, and/or reconstruction‡	5.01	8.52	1.70
(9) Spine osteotomy	0.06	0.11	1.75
(10) Foot/toes arthrodesis	0.41	0.73	1.77
(11) Femur/knee amputation	0.11	0.19	1.80
(12) Forearm/wrist arthrodesis	0.07	0.13	1.91
(13) Pelvis/hip excision	0.12	0.28	2.37
(14) Leg/ankle arthrodesis	0.10	0.24	2.38
(15) Nervous system spine and spinal cord anterior or anterolateral approach for extradural exploration/decompression	0.19	0.54	2.82
(16) Spine arthrodesis/deformity	0.05	0.15	3.17
(17) Femur/knee other procedures	0.03	0.11	3.44
(18) Pelvis/hip other procedures	0.05	0.18	3.55
(19) Shoulder other procedures	0.13	0.49	3.71
(20) Spine fracture and/or dislocation	0.09	0.36	3.97
(21) Leg/ankle other procedures	0.04	0.19	4.41
*Sorted by this column. †AMA CPT code category in the bottom quartile with >1% frequency among practitioners. ‡AMA CPT code category in the top quartile with >1% frequency among residents.			

humerus/elbow fracture and/or dislocation procedures and “other musculoskeletal-introduction or removal” procedures were the most frequently performed in both residency and early practice. On the basis of quartile segregation, we identified 15 AMA CPT code categories of procedures performed more frequently in early practice than in residency, and 10 AMA CPT code categories of procedures performed more frequently in residency than in early practice.

Parsing our findings by the most common individual AMA CPT codes (see Appendix) revealed more substantial differences. In residency, the 2 most commonly performed procedures in adults were total knee arthroplasty and total hip arthroplasty, which were performed 85% and 52% more frequently, respectively, than in early practice. Conversely, practitioners performed “treatment of intertrochanteric, peritrochanteric or subtrochanteric femoral fractures” 104%

TABLE VII Index of All Pediatric AMA CPT Code Categories Used by Both Practitioners and Residents, Sorted by Relative-Rate Quartiles

	Practitioner %	Resident %	Relative Rate*
Bottom quartile of AMA CPT code categories by relative rate			
(1) Pelvis/hip arthroscopy	0.85	0.15	0.18
(2) Integumentary system introduction	0.15	0.03	0.19
(3) Foot/toes arthroscopy	0.20	0.05	0.27
(4) Hand/fingers fracture and/or dislocation†	4.35	1.16	0.27
(5) Integumentary system repair - complex	0.64	0.20	0.31
(6) Nervous system spine and spinal cord neurorrhaphy	0.45	0.16	0.35
(7) Shoulder fracture and/or dislocation†	1.16	0.42	0.36
(8) Integumentary system debridement	0.20	0.08	0.38
(9) Nervous system spine and spinal cord neurorrhaphy with nerve graft, vein graft, or conduit	0.16	0.06	0.40
(10) Forearm/wrist fracture and/or dislocation†	5.79	2.37	0.41
(11) Femur/knee arthroscopy†	13.89	5.89	0.42
(12) Shoulder arthroscopy†	1.77	0.76	0.43
(13) Leg/ankle arthroscopy	0.54	0.25	0.46
(14) Integumentary system adjacent tissue transfer	0.26	0.12	0.48
(15) Humerus/elbow introduction or removal	0.43	0.21	0.49
(16) Integumentary system incision and drainage	0.69	0.33	0.49
(17) Integumentary system repair - intermediate	0.42	0.21	0.51
(18) Forearm/wrist arthroscopy	0.20	0.11	0.53
(19) Forearm/wrist excision†	1.02	0.55	0.54
(20) Integumentary system repair - simple	0.29	0.16	0.54
(21) Integumentary system - incision/excision†	5.56	3.05	0.55
Middle quartiles of AMA CPT code categories by relative rate			
(1) Foot/toes trauma - fracture and/or dislocation	1.05	0.61	0.58
(2) Leg/ankle trauma - fracture and/or dislocation	4.88	2.85	0.58
(3) Foot/toes introduction or removal	0.27	0.18	0.67
(4) Nervous system spine and spinal cord neuroplasty	0.58	0.39	0.68
(5) Humerus/elbow fracture and/or dislocation	11.80	8.18	0.69
(6) Hand/fingers incision	1.41	1.03	0.73
(7) Humerus/elbow arthroscopy	0.26	0.19	0.76
(8) Femur/knee trauma - manipulation	0.17	0.13	0.77
(9) Integumentary system excision - benign	0.13	0.10	0.77
(10) Other musculoskeletal excision	0.68	0.53	0.77
(11) Other musculoskeletal other procedures	0.36	0.28	0.78
(12) Hand/fingers excision	0.59	0.47	0.80
(13) Other musculoskeletal repair, revision, or reconstruction	0.35	0.30	0.86
(14) Humerus/elbow incision	0.27	0.24	0.86
(15) Shoulder incision	0.12	0.10	0.90
(16) Forearm/wrist incision	0.24	0.23	0.94
(17) Integumentary system skin grafts	0.27	0.26	0.94
(18) Hand/fingers repair, revision, and/or reconstruction	2.20	2.12	0.96
(19) Forearm/wrist repair, revision, and/or reconstruction	1.07	1.14	1.07
(20) Femur/knee trauma - fracture and/or dislocation	2.75	3.02	1.10
(21) Other musculoskeletal - introduction or removal	8.37	9.21	1.10
(22) Femur/knee excision	0.93	1.12	1.20
(23) Femur/knee incision	0.87	1.06	1.21
(24) Hand/fingers amputation	0.29	0.36	1.24

continued

TABLE VII (continued)

	Practitioner %	Resident %	Relative Rate*
(25) Humerus/elbow repair, revision, and/or reconstruction	0.43	0.53	1.24
(26) Leg/ankle excision	0.74	0.94	1.27
(27) Shoulder excision	0.19	0.26	1.34
(28) Pelvis/hip introduction or removal	0.80	1.09	1.36
(29) Pelvis/hip trauma - fracture and/or dislocation	1.12	1.56	1.39
(30) Foot/toes incision	0.29	0.46	1.58
(31) Foot/toes excision	0.65	1.12	1.71
(32) Humerus/elbow excision	0.25	0.44	1.75
(33) Leg/ankle incision	1.72	3.19	1.85
(34) Nervous system spine and spinal cord posterior extradural laminotomy or laminectomy for exploration/decompression of neural elements or excision of herniated intervertebral disc	0.15	0.28	1.91
(35) Femur/knee repair, revision, and/or reconstruction	3.08	6.16	2.00
(36) Leg/ankle amputation	0.10	0.21	2.04
(37) Foot/toes amputation	0.13	0.27	2.08
(38) Pelvis/hip repair, revision, and/or reconstruction	1.99	4.37	2.19
(39) Pelvis/hip incision	1.15	2.68	2.33
Top quartile of AMA CPT code categories by relative rate			
(1) Shoulder repair, revision, and/or reconstruction	0.17	0.42	2.42
(2) Pelvis/hip other procedures	0.12	0.29	2.47
(3) Spine osteotomy†	0.49	1.25	2.55
(4) Foot/toes repair, revision, and/or reconstruction‡	1.95	5.27	2.70
(5) Leg/ankle repair, revision, and/or reconstruction‡	2.20	6.16	2.80
(6) Spine arthrodesis/deformity†	1.05	2.99	2.84
(7) Shoulder other procedures	0.04	0.11	2.92
(8) Femur/knee introduction or removal	0.07	0.20	2.94
(9) Leg/ankle other procedures	0.08	0.25	3.13
(10) Spine instrumentation†	1.34	4.23	3.16
(11) Foot/toes arthrodesis	0.20	0.62	3.17
(12) Pelvis/hip excision	0.11	0.36	3.31
(13) Spine arthrodesis/anterior	0.05	0.20	4.21
(14) Femur/knee other procedures	0.06	0.28	4.42
(15) Foot/toes other procedures	0.04	0.20	4.76
(16) Spine fracture and/or dislocation	0.04	0.18	4.88
(17) Pelvis/hip trauma - manipulation	0.01	0.11	7.74
(18) Hand/fingers other procedures	0.02	0.13	7.80
(19) Spine other procedures	0.05	0.48	10.14
(20) Spine arthrodesis/posterior‡	0.16	2.03	12.64
(21) Spine exploration	0.01	0.18	12.94
(22) Nervous system spine and spinal cord anterior or anterolateral approach for extradural exploration/decompression	0.02	0.28	14.00
*Sorted by this column. †AMA CPT code category in the bottom quartile with >1% frequency among practitioners. ‡AMA CPT code category in the top quartile with >1% frequency among residents.			

more frequently than did residents. For pediatric cases, residents were exposed to pediatric spinal deformity and instrumentation procedures 176% to 179% more frequently than early practitioners, and were exposed to 64% to 74% fewer knee arthroscopic procedures. These dis-

crepancies among the most common cases highlight some incongruencies between resident exposure and practice experience.

Clearly, orthopaedic resident education involves the acquisition of relevant knowledge, skills, and behaviors. Specific

operative skills and techniques learned during residency form one critical element of this educational process. We have identified some areas that may need attention to better align the operative experience in residency to that of early practice. In particular, the subanalysis of the individual AMA CPT codes identified key discrepancies in exposure to specific procedures.

Our analysis focused on case volume and the relative frequency of AMA CPT code categories in comparing residency training with practice. However, volume alone is not sufficient to determine the adequacy of residency training. Mastery of one procedure may have a strong influence on skill transfer to and ultimate mastery of another procedure in a different anatomical location or patient population. Exposure to the varied and complex anatomy of the musculoskeletal system has value regardless of the actual surgical procedure. Residency education generally includes a broad spectrum of exposures to introduce trainees to potential fields of subspecialization.

This investigation and the comparisons we have made between exposure during residency and that of early practice may be confounded by early practice focus on skills acquired during fellowship training. In 2015, 91.7% of graduating orthopaedic surgery residents pursued fellowship training⁵. A review of data from the ABOS Part II examination from 2003 to 2013 showed that the percentage of cases performed within the fellowship subspecialty area increased during that decade⁶. Residents are often exposed to surgeons with practices that have evolved to deliver tertiary/quaternary care with a level of complexity not frequently seen in early practice. The discrepancies we found between procedures performed during residency compared with early practice likely partially reflect both this preferred subspecialty procedure focus and differences in practice complexity between residency training programs and early practice. The discrepancies may also be related to patterns of referring patients to academic training centers and the strong community-practice bias in the ABOS sample.

With respect to limitations of this study, we were unable to directly link the 2 databases; however, because 81% of the 2013 to 2015 Part II candidates (1,785 of 2,205) graduated from U.S. Orthopaedic residency training programs in 2010 to 2012, the 2 groups of surgeons are highly congruent. During the time when the current ACGME dataset was reported, there were no guidelines defining how residents should report their surgical exposure. Thus, the data used in this study do not inform us as to what level of involvement residents had during the operative procedures they reported in residency. Another limitation involves reporting accuracy and potential case bias. Residents are expected to log every case performed in residency, but their AMA CPT coding may be inaccurate as it relies on self-reporting⁷. In addition, residents are generally less familiar with the attributable relative value unit (RVU) basis for AMA CPT codes than are practicing surgeons. Potential differences in reporting AMA CPT codes are mitigated by the fact that we collapsed our original set of 3,479 unique CPT codes into 88 AMA CPT code categories, so it is unlikely that a lack of RVU knowledge would impact the code-category findings.

Although all consecutive surgical cases for the 6-month collection period are attested by each practitioner's hospital or

ambulatory surgical center medical records department, it is possible that some candidates may avoid performing more difficult cases during the case collection period because they believe that doing so may improve their odds of passing the Part II ABOS certifying examination. As a result, the dataset for the cases performed early in practice may be enriched with simpler cases.

Our results are not applicable to any specific residency experience. Some degree of variation in training experience is expected as a result of the natural differences in the occurrence of musculoskeletal pathology and faculty practice profiles in different programs. The generalizability of the findings should be recognized in this light.

In conclusion, we directly compared U.S. Orthopaedic surgical training exposure to actual practice experience, and our findings can help to guide orthopaedic graduate medical education to improve the face validity of residency training. We found overall robust congruency between residency and early practice. However, there is an opportunity to better define case types and minimum numbers to better ensure that residents are exposed to an adequate number of the commonly performed procedures seen in early practice, regardless of fellowship training.

Appendix

eA Tables showing the 25 most common AMA CPT codes for adult cases and pediatric cases, sorted by resident and practitioner case frequency, and tables listing all CPT codes used in the adult data analysis and the pediatric data analysis, with corresponding CPT code descriptions, are available with the online version of this article as a data supplement at [jbjs.org \(http://links.lww.com/JBJS/E665\)](http://links.lww.com/JBJS/E665). ■

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