Emergency medicine provider efficiency: the learning curve, equilibration and point of diminishing returns

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ABSTRACT

Objective This study described the spectrum of emergency department (ED) physician performance correlating annual workload, experience and facility issues.

Methods Retrospective review reported physician hours worked comparing productivity measures—patients per hour (PPH) or relative value unit (RVU) per hour, as 'best fit' trend line and facility volume subgroups by analysis of variance.

Results 912 physicians evaluated 2,407,833 patients in 61 ED. Staff productivity was 1.72±0.44 PPH (1.2±0.30–2.1±0.32 PPH) and 4.43±1.21 RVU/h (2.9±0.80–5.4±0.82 RVU/h). There was less variation with facility size 2.58±0.36 (2.41±0.22–2.72±0.37 RVU/visit) from smaller to larger (p<0.001). Maximal efficiency occurs at 5.0 RVU/h generated at 1550 annual hours (130 monthly) compared with 1800 h full-time equivalent (FTE) physicians (R²=0.084). Productivity begins at 4.0 RVU/h for casual (<250 h/year), 4.4 RVU/h for part time (<500 h), achieving equilibrium (5.0 RVU/h) for three-quarters to full time (1250–1800 h) with a decline in full-time providers (2000–2500 h/year). Efficiency was less in smaller ED less than 15,000 (1.22±0.30 PPH, 2.95±0.80 RVU/h) compared with larger than 45,000 (2.07±0.32 PPH, 5.43±0.82 RVU/h; p<0.001). The RVU/visit generated were less varied (2.41±0.22) in smaller versus (2.64±0.38) larger facilities with a 2.8 RVU/h equilibration point (p<0.001).

Conclusion Maximal productivity is reached at 86% (1550 h) annual workload and efficiency declines at conventional FTE (~1800 h). A distinct ‘learning curve’ was found in newer, casual providers and smaller facilities.

Another concept related to this model is that of ‘diminishing marginal productivity’ relating labour factors to a fixed plot of land described by Malthus in 1798. This agricultural productivity model was quantified by Clark in 1899. ‘Put only one man on a square mile of prairie and he will get a rich return. Two laborers on the same land and you will get less per man, and if you enlarge this factor to ten, the last man will get wages only.’

The more modern rendition of this concept is the ‘law of diminishing returns’, rendered by Hicks in 1934, focused not on the macroeconomic concept of average productivity (AP), in which the absolute ratio of output to labour (AP=Q/L) is monitored, but on the microeconomic concept of marginal productivity (MP), focusing on the change of output over the change in labour (MP=ΔQ/ΔL). Here, additional productivity is extracted with additional labour input with all other variables fixed. Eventually, however, additional labour input is not accompanied by greater product output and a saturation point is reached.

The physician care resources required are most commonly predicted by the number of patients evaluated. A single emergency department (ED) physician staffing model can be used for less than 17,500 patients, physician and midlevel for 17,500–25,000 patients and multiple physician model for more than 25,000 annual visits as an approximation.

There are numerous factors affecting ED provider efficiency, exclusive of the physician level of expertise, proficiency and work ethic. The two most obvious factors are the number of patients presenting for care, accompanied by their acuity, often with the admission rate used as a de-facto endpoint. The next area of concern offered by physicians is the impact of the amount of laboratory and radiology turnaround time. Another area of focus is the adequacy and effectiveness of nursing and ancillary staffing.

Finally, and at times reluctantly, physicians must critique their own work habits and productivity in terms of maximum efficiency—the emergency medicine ‘sweet spot’. This optimal efficiency is driven by adequate training and work experience, generating an effective diagnostic and testing process. This longitudinal derivation is acknowledged by most practitioners to be associated with confidence and decisiveness in making critical decisions without undue perseverance.

There is probably less focus on the day-to-day effectiveness; however, there is a declining work product associated, as well, with excess work stress related to overwork. The ED physician’s well-honed skill set can become overextended with...
increased work hours, excessive shift rotation and work or personal distractions.

The goals of the investigation were to ask what is the most optimal physician workload associated with maximum efficiency in the ED setting. Secondly, is this efficiency modified by facility or volume? Finally, what are the potential staffing and economic effects of this decision-making?

METHODS
Study design
The ED practitioner efficiency study was a retrospective evaluation of all ED visits evaluated and billed over a 2-year period (2005–6) by a consortium of emergency medicine providers. Individual ED physician efficiency data points were correlated with individual work experience, annual workload, and profiled on facility size.

Methods of measurement, data collection and processing
Provider efficiency is defined as patients per hour (PPH), evaluated contingent on the time required to be seen by the provider. The resource-based value scale (RBRVS) based on the Harvard University study published by Hsiao and colleagues8 9 factored the procedural worth and geographical location to determine a monetary value of the intervention. The currency of this template is the resource-based relative value unit (RVU) factoring physician work, practice costs and malpractice expense.

Setting
This patient care information was abstracted from the Apollo Information Services, Inc. (Fort Myers, Florida, USA) database that has analysed over 10 000 000 patient ED encounters since 1998. This patient evaluation information was merged with a payroll information database, Lawson Software (Minneapolis, Minnesota, USA).

Selection of participants
We abstracted a convenience sample of efficiency in which data were recorded as a RVU (measured per hour) compared with total hours worked during the calendar years 2005 and 2006. Further analysis was predetermined to include the effect of hospital size measured as average ED volume in small (less than 15 000 visits), medium (15 001–50 000 visits), moderate (50 001–45 000 visits) and large (more than 45 001 annual facility visits) (table 1).

Protocol
This study was exempted from the investigational review board requirement, reporting only unassigned medical billing analysis. No protected patient medical information was revealed, and no study interventions that directly affected patient care were utilised.

Table 1  ED physician provider environments

<table>
<thead>
<tr>
<th>ED size</th>
<th>Practitioners (%)</th>
<th>Volume (annual patient visits)</th>
<th>Representative type</th>
<th>Physician coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>15.7</td>
<td>&lt;15 000</td>
<td>Rural</td>
<td>Single</td>
</tr>
<tr>
<td>Medium</td>
<td>35.6</td>
<td>15 001–30 000</td>
<td>Suburban Urban</td>
<td>Double</td>
</tr>
<tr>
<td>Moderate</td>
<td>29.3</td>
<td>30 001–45 000</td>
<td>Complex Suburban</td>
<td>Triple</td>
</tr>
<tr>
<td>Large</td>
<td>19.4</td>
<td>&gt;45 001</td>
<td>Referral Urban</td>
<td>Quadruple</td>
</tr>
</tbody>
</table>

ED, emergency department.

Primary data analysis
Data were collected and recorded in a Microsoft Excel (Redmond, Washington, USA) database and further analysed by G* Power 2 Statistical package (Dusseldorf, Germany) for power and calculations with SPSS for Windows 15.0 for analysis of variance (ANOVA) statistical comparisons. Efficiency data were represented graphically with annual hours worked on the x-axis and productivity measures on the y-axis. These data were represented as a best-fit trend line utilising a sixth order polynomial equation reported as a regression calculation (p<0.05). Differences between the groups were analysed using ANOVA (p<0.05) statistical comparisons of multiple groups.

Outcome measures
The primary endpoint was work product defined as PPH or RVU modified by hours worked as mean and SD. The secondary endpoints were determined per-experimentally to include facility efficiency defined by patient volume as modifiers, including PPH, RVU/h and RVU/visit.

Power/sample size
This study was judged to be adequately powered to detect differences between groups if a 99% CI with a 5% margin of error (±) and response distribution of 50% for moderate effects was achieved by analysing the sample size chosen from the universe of possible subjects.

RESULTS
Characteristics of study subjects
Data were reported on 913 physician healthcare providers, with three eliminated due to incomplete data over a 2-year period from 2005 and 2006. They evaluated 2 404 833 patients in 61 different hospital ED utilising 1 352 285 clinical hours of coverage total generating 6 525 298 RVU of patient care activity (table 2).

The majority of 912 practitioners provided care at medium (35.6%), moderate (29.3%) and larger (19.4%) sites, whereas smaller facilities (15.7%) were in the minority.

Main results
Our power calculations reveal that for our overall provider analysis with six predictors, including all polynomial effects, a sample size of 915, and an α level of 0.001, the multiple regression analysis had a power of 0.999 to detect moderate effects. Likewise, the provider facility based ANOVA calculation with four categories found a power of 0.999 to detect moderate effects. Volume accounted for 10% of the variance in efficiency, but a level of 0.001, the multiple regression analysis had a power of 0.999 to detect moderate effects. Volume accounted for 10% of the variance in efficiency measures for both comparisons.

Overall staffing efficiency was 1.72±0.44 (PPH) increasing proportionally with patient volume with a range of 1.22±0.30 PPH at the smaller facilities compared with 2.1 PPH at the larger facilities (p<0.001) (figure 1). The RVU/h followed a similar decreasing with facility size trend, with an average of 4.43±1.21, ranging from 2.95±0.80 at smaller facilities to 5.43±0.85 RVU/h at the largest sites (p<0.001) (table 2). The individual physician productivity had less variation, with an average of 2.59±0.36 RVU/visit with a range of 2.42±0.21 for the smallest and 2.72±0.37 RVU/visit at the moderate-sized sites (p<0.001).

The temporal trend in physician productivity finds a steep learning curve for casual practitioners (figure 2). Our best-fit trend line finds that practitioners working casually, less 250 h annually at the same site, are least productive, generating 4.0 RVU/h (R²=0.084, p<0.05). Productivity increases at a constant rate and at 500 h of average annual clinical activity generates 4.4...
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projected costs and not charges based on the RBRVS service
with its origins in the 1992 Medicare change in renumeration for
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component. The RVU is based on the original Harvard Univer-
multiplied by a conversion factor and geographical case modi
practice expense (44%) and professional liability insurance (4%)
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larger (1.7–2.1 PPH) versus smaller facilities (1.2–1.7 PPH) finds
a progressive increase in RVU generated per hour from 2.9 in
small, 4.3 in medium, 4.7 in moderate and 5.4 in large facilities
(p<0.001) (figure 3A).

The equilibration point was 2.7 RVU generated per hour
consistently until a decline was again noted when at least
2000 h were worked annually. The smallest facility seemed to
have less variation with 1.0 PPH and 2.8 RVU/h productivity
maintained through the span of work activity (figure 3B,C).

DISCUSSION

There are a vast number of recommended ED staffing
approaches. Historically, the average number of patient
encounters in the ED is 2.0 (1.8–2.2) PPH evaluated.10 As
systems have matured or simply become more stressed, the
mean number of patient encounters has increased to 2.25
(2.0–2.5) on average.

Another primary endpoint finds the RVU productivity model
with its origins in the 1992 Medicare change in renumeration for
projected costs and not charges based on the RBRVS service
 provision.11 The cost is calculated by physician work (52%),
practice expense (44%) and professional liability insurance (4%)
multiplied by a conversion factor and geographical case modifier.
The major factor in this analysis is the physician work
component. The RVU is based on the original Harvard University
study. The RVU includes: (1) time to perform service; (2)
technical skill; (3) physical effort; (4) required mental effort and
(5) judgement and stress due to potential patient risk, and is
revaluated by the Center for Medicare and Medicaid Services
every 5 years.

In summary, the RBRVS assigns a relative value to a procedure
performed by a provider adjusted to a local cost of a geographical
region, multiplied by a fixed conversion factor to determine the
overall healthcare cost.

Analysis of our secondary endpoint is comparable to a previous
work. There is an interesting non-linear distribution of workforce
compared with annual visits. Small facilities (less than 20 000
visits) are routinely associated with efficiencies of 1.96 PPH,
modest (20–30 K) of 2.05 PPH, moderate (30–40 K) of 2.41 PPH
and large (40–50 K) facilities of 2.06 PPH.12 The maximal efficiency
was found in the moderately sized facility, with lesser efficiency
in the small followed by the largest facilities.

Although the more common measure of ED physician
productivity is PPH evaluated, we feel that the RVU/h measure
better evaluated the complexity of the ED patient and allowed us
to define the ‘learning curve’ and marginal productivity concepts
relating to these data. Our staffing and productivity benchmarks
were 1.78 (1.1–2.1) PPH and 4.48 (2.6–5.6) RVU/h, with
efficiency increasing proportionally with patient volume evaluated.

Our primary and secondary endpoints were more than
adequately powered to state our conclusions concerning overall
provider efficiency within the predicted limits of our polynomial
plotting methodology, as well as that categorised by facility size
ANOVA analysis.

There were three distinct zones of productivity defined by our
best-fit trend line for the ED population (table 5). The resulting
correlation was significant but of modest effect, with 10% of the
variance due to the studied variable. First, there was a zone of
increasing productivity or the ‘learning curve’ in which RVU/h
increased rapidly at first then at a more moderate rate. Second,
the equilibration phase in which RVU/h were constant is when
the emergency medicine efficiency ‘sweet spot’ was reached.
Here, the learning curve has plateaued to a point of maximal

### Table 2 | Data summary of patient visits versus hours worked subdivided by practice site size

<table>
<thead>
<tr>
<th>Annual volume</th>
<th>Practitioners (n)</th>
<th>Facilities (n)</th>
<th>Clinical hours</th>
<th>Patient visits</th>
<th>Total RVU</th>
<th>PPH, mean±SD</th>
<th>RVU/h, mean±SD</th>
<th>RVU/visit, mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>To 15 K</td>
<td>143</td>
<td>12</td>
<td>178 139</td>
<td>192 099</td>
<td>469 363</td>
<td>1.2198±0.30362</td>
<td>2.9528±0.80770</td>
<td>2.4156±0.21992</td>
</tr>
<tr>
<td>15–30 K</td>
<td>325</td>
<td>27</td>
<td>503 478</td>
<td>882 568</td>
<td>2 249 359</td>
<td>1.7247±0.37222</td>
<td>4.3188±0.96477</td>
<td>2.5197±0.34015</td>
</tr>
<tr>
<td>30–45 K</td>
<td>267</td>
<td>15</td>
<td>374 647</td>
<td>705 069</td>
<td>1 935 806</td>
<td>1.7343±0.39492</td>
<td>4.7051±1.08634</td>
<td>2.7228±0.37609</td>
</tr>
<tr>
<td>45+ K</td>
<td>177</td>
<td>7</td>
<td>296 021</td>
<td>625 077</td>
<td>1 670 770</td>
<td>2.0738±0.32434</td>
<td>5.4327±0.82975</td>
<td>2.6472±0.38039</td>
</tr>
<tr>
<td>Total</td>
<td>912</td>
<td>61</td>
<td>1 352 285</td>
<td>2 404 833</td>
<td>6 325 298</td>
<td>1.7161±0.43949</td>
<td>4.4339±1.21439</td>
<td>2.5876±0.36095</td>
</tr>
</tbody>
</table>

ANOVA, analysis of variance (p<0.05); PPH, patients per hour; RVU, relative value unit.

RVU/h. Maximal efficiency is reached in the 1250–1800 annual
hour range, with 5.0 RVU/h generated. Interestingly, there was
a point of maximal return at approximately 1550 h annually,
with a significant decline noted after 2000 h, and even further
after 2500 h worked annually.

There was similar trending noted based on the size of the
facility. Higher ED patient volume equated with better effi-
ciency with 2.4–2.5 RVU generated per visit in small (15 K) to
medium (20 K) sized facilities increasing to 2.6–2.7 RVU/visit in
larger (50–45 K) facilities (p<0.001) (figure 3A).

Factoring in the increased number of patients evaluated at
larger (1.7–2.1 PPH) versus smaller facilities (1.2–1.7 PPH) finds
a progressive increase in RVU generated per hour from 2.9 in
small, 4.3 in medium, 4.7 in moderate and 5.4 in large facilities
(p<0.001) (figure 3B, C).

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**Figure 1** Overall physician productivity measured as patients per hour compared with annual workload. Regression correlation (R²=0.084, p<0.05).
efficiency. This phase optimises ‘parallel process thinking’ rather than ‘serial patient management’; the physician simultaneously, rather than sequentially, handles the multitude of tasks required to manage emergency patients optimally. Third, there is a phase of diminished productivity in which the RVU produced per hour are decreasing. This phase can be best described as one potential manifestation of the physician ‘burnout’ phenomenon. It is crucial to recognise that the learning curve can exist even in an experienced provider in a new facility, as unfamiliar procedures and processes are encountered. The corollary suggests that a disproportionate number of part-time compared with full-time physicians can have an adverse impact on departmental efficiency. This trend may also be accentuated with locum tenens physicians who may not be adept at regional care practices and standards. Likewise, the use of a significant number of ‘new’, less experienced providers may require staffing accommodations until all practitioners are ‘up to speed’. Finally, stable, experienced full-time physicians may become complacent and limit their workload autonomously. Remember that trend group data do not predict individual performance, especially relevant to the loss of productivity trend. Some of the best physicians include part-time or locum tenens physicians who may take maximum productivity even when exceeding the average full-time equivalent (FTE) (1800 h

Figure 2  Overall physician productivity measured as relative value unit (RVU) per hour compared with annual workload. Regression correlation ($R^2=0.084$, $p<0.05$).

![Figure 2](chart.png)

**Regression Correlation ($R^2 = 0.084$, $p<0.05$)**

Figure 3  Physician productivity based on emergency department volume. (A) Relative value unit (RVU) per visit. $p<0.001$; (B) Patients per hour. $p<0.001$; (C) RVU/h, $p<0.001$, analysis of variance (ANOVA).

![Figure 3](chart.png)
ED physician productivity

<table>
<thead>
<tr>
<th>Phase</th>
<th>Productivity (RVU/h)</th>
<th>Rate of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improving productivity 'learning curve'</td>
<td>Increasing</td>
<td>Moderate to rapid</td>
</tr>
<tr>
<td>Equilibrium 'sweet spot'</td>
<td>Constant</td>
<td>None</td>
</tr>
<tr>
<td>Diminishing productivity 'burnout'</td>
<td>Decreasing</td>
<td>Slow</td>
</tr>
</tbody>
</table>

ED, emergency department; RVU, relative value unit.

Table 3: ED physician productivity

- Diminishing productivity: 'burnout' - Decreasing, Rate of change: Slow

Interestingly, productivity seemed more stable in the smaller facilities. Their practitioners would stress self-reliance and their responsibility to maintain a steady flow in these solo staffed locations. There is an inability to shift work responsibilities to other practitioners, either ED physician colleagues or hospital consultants with patient overload.

Proper planning approaches included factoring for new or inexperienced practitioners, veteran burnout and facility vagaries to ensure safe staffing and patient safety.

Limitations

We acknowledge wide variation in practice dictated by both positive and negative efficiency influences. Improvements noted include better training, technology information systems and performance incentive plans driving provider efficiency. Detriments include adverse payor mix, adverse medical-legal environment, admission delays, facility overcrowding issues and suboptimal support staff.

The most commonly encountered dilemma is the non-uniform distribution of patients, with daytime activity associated with a 25–50% increase in patient flow, whereas at night a 25–50% decrease quantitatively at the same sites is often found. It is recognised, however, that this night time activity is complicated by an increase in patient complexity, increased psychosocial burden and lack of resources and programmes available.

The impact statements derived from this work were focused on the balance between quality and quantity to achieve maximal efficiency and effectiveness factoring in trends such as experience, the workload at hand and facility size. Important considerations include: first, the ‘learning curve’ for new or unfamiliar providers; second, the marginal productivity model in which efficiency is maximised below the acceptable FTE work equivalent; and third, the potential productivity trade-off based on facility size. Finally, we recognise the limits of group trending on the prediction of individual performance.

Competing interests None.

Contributors RBV participated in the analysis and interpretation of data, drafting of the manuscript, statistical analysis of the article, and has seen and approved the final version. RHN participated in the conception and design, acquisition of data, critical revision of the manuscript for important intellectual content, the administrative support of the article, and has seen and approved the final version. Both authors are affiliated with Apollo.

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REFERENCES