Whipple’s operation with a modified centralization concept: A model in low-volume Caribbean centers

Shamir O Cawich, Neil W Pearce, Vijay Naraynsingh, Parul Shukla, Rahul R Deshpande

Abstract
Conventional data suggest that complex operations, such as a pancreaticoduodenectomy (PD), should be limited to high volume centers. However, this is not practical in small, resource-poor countries in the Caribbean. In these settings, patients have no option but to have their PDs performed locally at low volumes, occasionally by general surgeons. In this paper, we review the evolution of the concept of the high-volume center and discuss the feasibility of applying this concept to low and middle-income nations. Specifically, we discuss a modification of this concept that may be considered when incorporating PD into low-volume and resource-poor countries, such as those in the Caribbean. This paper has two parts. First, we performed a literature review evaluating studies published on outcomes after PD in high volume centers. The data in the Caribbean is then examined and we discuss the incorporation of this operation into resource-poor hospitals with modifications of the centralization concept. In the authors’ opinions, most patients who require PD in the Caribbean do not have realistic opportunities to have surgery in high-volume centers in developed countries. In these settings, their only options are to have their operations in the resource-poor, low-volume settings in the Caribbean. However, post-operative outcomes may be improved, despite low-volumes, if a modified centralization concept is encouraged.

Key Words: Pancreas; Surgery; Pancreatectomy; Whipple’s; Pancreaticoduodenectomy
Core Tip: The published data generally support pancreaticoduodenectomies (PD) being reserved for high volume hospitals. However, this is not practical in resource-poor, low volume countries in the Caribbean. Nevertheless, we have documented good short-term outcomes after PD in this setting. In this paper we discuss a modified centralization concept used to incorporate PD into these low volume centers.

INTRODUCTION
Pancreaticoduodenectomy (PD) is a technically complex operation that is accompanied by high complication rates. Although post-operative morbidity has declined over the past 2-3 decades with better supportive care, 30%-50% of patients still experience post-operative complications[1]. Due to PD’s high-morbidity profile, specialized hospitals began to appear at the turn of the 21st century where hepatopancreatobiliary (HPB) services were concentrated. This drove the “high-volume center” concept in developed countries with large populations, and it was fueled by good outcome data emerging from these centers. A change in referral patterns followed, where patients with peri-ampullary lesions were sent to these experienced centers for multidisciplinary teams to perform PDs at high volumes. This was the birth of the era of service centralization and terminology evolved from “experienced centers”[2] to “high-volume centers”[3].

In this paper, we discuss our experience incorporating PD into this low-volume, resource-poor region.

DATA FROM HIGH-VOLUME CENTRES
At the turn of the 21st century, published data emerged to show that high volume centers performed PDs with significantly reduced overall morbidity[1-8], thirty-day mortality[1,8] readmission rates[3], cost[3,9], duration of hospital stay[3,9] and 5-year survival rates[1,8,10]. These data supported the principle of centralization - a concept that seemed predictable and intuitive on first glance.

However, a closer look at the existing data revealed that there was no standardized definition of “high volumes”, with researchers applying ad-hoc definitions that ranged from as low as 2 PDs annually[6,8] to as high as 125 PDs annually[11]. We conducted a systematic literature search across the PubMed, Medline and Google Scholar platforms seeking publications that defined “high-volume” hospitals, using the search terms: “high-volume”, “experienced”, “centers of excellence”, “referral centers” and “specialty centers”. The literature search was performed by two researchers and spanned the 27-year period from January 1, 1995 to December 31, 2021. All studies identified were retrieved and reviewed in detail by both researchers who extracted the following data: definition of high-volume center, mortality in low and high-volume centers and study population. We excluded studies that did not document these data, studies with missing data and duplicated studies. The results are outlined in Table 1[1-30]. Most studies demonstrated significant differences in 30-d mortality, but the definitions of “high volume” varied widely. Most papers in the literature quoted numbers ≥ 20 PDs per annum[1,3,4,9,16,17,25].

ARGUMENTS AGAINST REGIONALIZATION
Although data accumulated to support service centralization in developed countries, the concept faced several challenges.

Unclear definitions of “high volume”
With the presumption that medical literature will soon adopt a standardized definition of “high volume” equating to ≥ 20 PDs per annum (Table 1), there are few hospitals across the globe that would qualify as high-volume centers. This creates a logistic problem because it would be impractical for patients to be routed to few centers across the globe for PD. This is especially unrealistic in the...
| Author               | Peri-operative mortality | P       | Study population                                                                 | Definition of high volume (cases per annum) |
|---------------------|--------------------------|---------|----------------------------------------------------------------------------------|--------------------------------------------|
| Lieberman et al.[2] | Low volume: 18.9%        | High volume: 5.5% | 2233 PDs over 8 years in New York, USA from 1984-1991 | Minimal: < 10; Low: 10.50; High: > 50 |
|                     |                          |         |                                                                                   |                                             |
| Glasgow et al [9], 1996 |                         | 0.0009  | 1424 PDs using data from the California Office of Health Wide State Planning and Development from 1990-1994 | I (Low): 1-5; II: 6-10; III: 11-20; IV: 21-30; V: 31-50; VI (High): 50 |
| Sosa et al[3], 1998 | Low volume: 18.8%        | High volume: 0.9% | 449 PDs + 47 total pancreatectomies from 48 non-federal hospitals in Maryland, USA from 1990-1995 | Low: < 5; Medium: 5-19; High: > 20 |
|                     |                          |         |                                                                                   |                                             |
| Birkmeyer et al[1], 1999 | Low volume: 16%        | High volume: 4% | 7229 PDs from the US-based Medicare database from 1992-1995 | Very Low: < 1; Low: 1-2; Medium: 2-5; High: > 5 |
|                     |                          |         |                                                                                   |                                             |
| Gouma et al [12], 2000 | Low volume: 13.2%       | High volume: 8.1% (Cutoff III) | 1126 patients from 1994-1998 from the National Medical Registry in the Netherlands | I: < 5; II: 5-10; III: 10-25; IV: > 25 |
| Kottwall et al [4], 2002 | Low volume: 12.6%       | High volume: 9%                  | 24926 PDs from the US-based National Inpatient Database from 1988-1995 | Low: ≤ 1; High: > 1 |
|                     |                          |         |                                                                                   |                                             |
| Nordback et al [13], 2002 | Low volume: 13%         | High volume: 4%                  | 350 PDs from the National Hospital Discharge Database in Finland from 1990-1994 | Low: < 5; Medium: 5-10; High: > 10 |
|                     |                          |         |                                                                                   |                                             |
| Finlayson et al [14], 2003 | Low volume: 11%         | High volume: 3%                  | 3414 pancreatic resections (unspecified) from the US based Nationwide Medicare Database from 1994-1999 | Very Low: < 1; Low: 1-2; Medium: 3-4; High: 5-13; Very High: > 13 |
|                     |                          |         |                                                                                   |                                             |
| Ho et al[7], 2003 | Low volume: 14.6%        | High volume: 4.7% | 6709 PDs in California and Florida (from insurance claims) between 1988-1998 | Very Low: < 1; Low: 2-3; Medium: 4-9; High: > 10 |
|                     |                          |         |                                                                                   |                                             |
| Van Heek et al [15], 2005 | Low volume: 11.8%       | High volume: 3.8%                | Systematic review of studies reporting mortality in 1988 unspecified pancreatic resections in the Dutch Nationwide Registry from 1994-2004 | Very Low: < 5; Low: 5-9; Medium: 10-24; High: > 24 |
|                     |                          |         |                                                                                   |                                             |
| Feng et al[4], 2005 | Low volume: 8%           | High volume: 2% | 2592 PDs across 1101 hospitals using data from national Medicare database between 1995-1996 | Low Volume: ≤ 25; High Volume: > 25 |
|                     |                          |         |                                                                                   |                                             |
| McPhree et al [16], 2007 | Low volume: 11.1%       | High volume: 2.7%                | 39463 pancreatic resections from the US-based National Inpatient Sample Database from 1998-2003 (27289 PDs analyzed separately) | Low: < 5; Medium: 5-18; High: > 18 |
|                     |                          |         |                                                                                   |                                             |
| Riall et al[17], 2007 | Low volume: 7.4%         | High volume: 3.0%                | 3189 pancreatic resections in Texas using the Texas Hospital Inpatient Discharge Public Use Data File from 1999-2004 | Low: < 10; High: > 10 |
|                     |                          |         |                                                                                   |                                             |
| Megaid et al [18], 2008 | Low volume: 11.1%       | High volume: 5.22%               | 7558 pancreatic resections from the Nationwide Inpatient Sample from 1998-2003 | Low: 1-18; High: > 18; |
|                     |                          |         |                                                                                   |                                             |
| Billimora et al [8], 2008 | Low volume: 15.4%       | High volume: 4.99%               | 13107 unspecified pancreatic resections in 1454 hospitals via ACS National Cancer Database from 1994-1999 | Low: < 2; Medium: 2-9; High: ≥ 10 |
|                     |                          |         |                                                                                   |                                             |
| Balzano et al [19], 2008 | Low volume: 12.4%       | High volume: 2.6%                | 1576 patients (1044 PDs) from 221 hospitals in Italy using data from Ministry of Health in the year 2003 | Low Volume: < 5; Medium: 6-13; High: 14-51; Very High: > 52 |
|                     |                          |         |                                                                                   |                                             |
| Gasper et al [20], 2009 | Low volume: 50%         | High volume: 10%                 | Pooled estimated effects in favour of high-volume hospitals: OR 0.25 (95%CI 0.15-0.41) | Low: < 5; Medium: 5-49; High: > 50 |
|                     |                          |         |                                                                                   |                                             |
| Teh et al [21], 2009 | OR mortality (95%CI): 4.0 (3.1-5.1) | OR mortality (95%CI): 1.7 (1.3-2.4) | 103222 patients (76273 PDs) from the Nationwide Inpatient Sample in USA between 1988-2003 | Very Low: 3; Low: 3-5; Medium: 6-11; High: 12-23; Very High: 24-35; Extra: > 36 |
|                     |                          |         |                                                                                   |                                             |
| Nathan et al [11], 2009 | Low volume: 33.7%       | High volume: 33.5%               | 8251 PDs from the State Inpatient Databases for Florida, Maryland, and New York from 1998-2005 | Low: < 25; Mid: 25-124; High ≥ 125 |
|                     |                          |         |                                                                                   |                                             |
| Schmidt et al [1], 2010 | Low volume: 4%          | High volume: 2%                  | 1003 PDs at Indiana University across two periods 1980-2003 and 2004-2007 | Low: < 20; High: > 20 |
|                     |                          |         |                                                                                   |                                             |
| Grooiker et al [22], 2011 | Low volume: 5%          | High volume: 2%                  | Pooled estimated effects in favour of high-volume hospitals: OR 0.16-0.66 | Metanalysis of 154626 patients across 14 studies undergoing unspecified pancreatic resections from 1970-2010 |
|                     |                          |         |                                                                                   | Pooled volume groups as defined in individual studies; Lowest: 1-5; Highest: 7-36 |
| La Torre et al [10], 2012 | Low volume: 2.5%        | High volume: 2.1%                | Systematic literature review of patients undergoing pancreaticctomy across 18 studies | Low: 9-8; Medium: 9-12; High: 13-18; Very High: > 19 |
Caribbean where many patients are not able to afford care in developed countries. The region has some of the poorest countries in the Western Hemisphere and many patients in these territories do not have health insurance.

### Data generalization

Healthcare personnel should exercise good judgement when interpreting the available data. Pawlik et al [31] made the point that volume-outcome relationships are one way to judge hospitals, but are non-informative about any specific hospital - apart from those from which the data was collected. In other words, it cannot be used to generalize outcomes in every low or high-volume hospital. Thus, if a low-volume hospital published data to show good outcomes, it should trump simple volume data.

Additionally, there are many factors that may skew outcomes data: Firstly, within high volume centers, surgeons do not have equivalent experiences, case volumes or clinical outcomes[1,31-34]. Secondly, some high-volume centers may end up treating higher-risk cases while some community or teaching hospitals may treat more indigent patients, potentially skewing outcome data. Thirdly, volume-related data only provides information on patients who underwent PDs, but excludes any useful information on clinician judgement, expertise and decision making when choosing patients for surgery[31]. This critical aspect of care for patients with peri-ampullary carcinomas does not appear in any volume-based data.

### Surgeon volumes

To be able to complete a PD, surgeons must accrue experience through repetition of the operative steps. Some have argued that PD outcomes are less dependent on hospital volume and more dependent on the technical competence of the operating surgeon[1,2,5,7,13,35]. Numerous authors have demonstrated the association between increasing individual surgeon volume and improved PD outcomes[1,2,5,7,13,35]. Published data show that high-volume surgeons complete PD with significantly lower mean blood loss [1,2], shorter operating time[1] and greater nodal harvest[1] when compared to low-volume surgeons. Nordback et al[13] also demonstrated that 86% of post-PD deaths were due to surgical or technical complications.

However, it is difficult to meaningfully interpret these data because there is no standardized definition of a “high-volume surgeon”, with researchers applying ad-hoc definitions that range from as low as 3 PDs annually[13] to as high as 50 PDs annually[2,20,30]. We conducted a systematic literature search across the PubMed, Medline and Google Scholar platforms seeking publications that defined: “high-volume” surgeons, using the search terms: “high-volume”, “experienced”, “subspecialty trained” and “specialized”. The literature search was performed by two researchers and spanned the 27-year period from January 1, 1995 to December 31, 2021. Table 2 outlines the results[1,2,3,13,35] and shows a large variation in the definition of “high volume surgeons”.

Schmidt et al[1] introduced the “experienced surgeon” concept being distinct from a high-volume surgeon. They defined an experienced surgeon as one who had performed > 50 PDs in their career. In other words, they suggested that the cumulative experience was important unlike a high-volume

| Authors      | Volume | Morbidity | Mortality | HR | OR | CI       | Notes |
|--------------|--------|-----------|-----------|----|----|---------|-------|
| Alsasser et al [23], 2012 | 32.2% (1-yr mortality) | 26.2% (1-yr mortality) | < 0.001 | 9566 patients who underwent PD or total pancreatectomy in Germany from 2006-2009 | Low: < 32; High: > 32 |
| Bliss et al[24], 2014 | 8.1% | 3.1% | < 0.001 | 19024 PDs using the US based National Cancer | Low: < 5; Medium: 5-18; High: > 18; Very High: > 50 |
| Derogar et al [25], 2015 | 60% greater mortality risk | NR | HR 1.60, 1.04 to 2.48 | 3298 pancreatic resections from the Swedish National Register (2818 PDs not separately reported) from 1990-2010 | 24 (not clearly defined) |
| Hata et al[26], 2016 | Overall pooled OR for mortality in favour of high-volume hospitals: OR 2.37 (95% CI 1.95-2.88) | 0.09 | Metanalysis of 58023 patients undergoing PD across 13 studies based on nationwide databases from 11 countries | Low: 1-19; Medium: 20-29; High: > 30 |
| Briceno et al [27], 2017 | 5.5% | 2.6% | < 0.001 | 19024 PDs using the US based National Cancer Database from 2010-2015 | Low: < 10; Medium: 10-20; High: > 20 per year |
| El Amrani et al[28], 2018 | 4.4% | 3.4% | 0.047 | 10632 patients undergoing distal pancreatectomy from 2009-2018 from a national French database | Low Volume: ≤ 10; High Volume: > 10 |
| Krautz et al [29], 2018 | 10.4% | 8.1% | NS | Analysis of 60858 patients undergoing major pancreatic surgery (unspecified) from a German National Database from 2009-2014 | Very Low: < 8; Low: 8-18; Medium: 19-41; High: 32-58; Very High: > 59 |
| Balzano et al [30], 2020 | 8.1% | 4.4% | < 0.001 | Multicenter study of 7631 PDs (12662 pancreatic resections) in 395 Italian hospitals from 2014-2016 | Very Low: 0-10; Low: 10-25; Medium: 25-60; High: 60-166; Very High > 167 |

NR: Not reported; PD: Pancreatico-duodenectomy; US: United States; ACS: American College of Surgeons; HR: Hazard ratio; OR: Odds ratio; CI: Confidence intervals.
Table 2 Summary of studies comparing peri-operative mortality according to surgeon volumes

| Author               | Low volume surgeon, % | High volume surgeon, % | Study population                                         | Definition of low-volume surgeon | Definition of high-volume surgeon |
|----------------------|-----------------------|------------------------|----------------------------------------------------------|----------------------------------|----------------------------------|
| Lieberman et al [2], 1995 | 15.5                  | 4.7                    | >9 PDs over 8 years in New York State                     | < 9 cases experience            | > 41 cases experience            |
| Sosa et al [3], 1998  | 12                    | 1.8                    | 449 PDs + 47 total pancreatectomies from non-federal facilities in Maryland, USA | < 5 PD annually                  | > 50 PD annually                  |
| Nordback et al [13], 2002 | 14                  | 3                      | 350 PDs in 33 hospitals by 98 surgeons                    | < 1 annually                     | > 3 annually                     |
| Schmidt et al [1], 2010 | 4                    | 2                      | 1003 PDs at Indiana University across 2 periods          | < 20 annually                    | > 20 PD annually                  |
| Eppsteiner et al [35], 2009 | 6.4                  | 2.4                    | 3581 pancreatic resections from the National Inpatient Sample Database | < 5 annually                     | ≥ 5 annually                     |

PD: Pancreatico-duodenectomy.

surgeon which was time dependent. Schmidt et al [1] were able to demonstrate that, compared to their less-experienced colleagues, experienced surgeons performed more PDs with vein resections (96% vs 4%) and had significantly lower overall morbidity, pancreatic leak rates, operative blood loss and mean operating time. Importantly, they showed that experienced surgeons who currently performed PDs at low volumes had equivalent outcomes to high-volume surgeons.

Schmidt et al [1] suggested that a pancreatic surgeon needs to accrue 50 PDs before the improvement in technical operative skills begins to plateau. Tseng et al [36] suggested that in their experience, surgeons continued to acquire skills and technical expertise even when approaching 200 PDs. Although there is no consensus, and regardless of a time or case-load dependent definition, we believe that pancreatic surgeons continue to gain experience by developing operative maneuvers, recognizing avoidable pitfalls and learning how to get out of trouble when PDs don’t go smoothly. They also develop mature judgement that is important for appropriate patient selection. We cannot downplay the importance of developing inter-personal relationships over time that facilitate better working relationships with colleagues in other specialities to enhance supportive post-operative care. These are lessons that can only be learned with proper surgical mentorship and accrued experience [1,37].

**Combined team expertise**

Taking it a step further, PDs are quite unforgiving when complications arise. When they do, expert multidisciplinary care is required to prevent bad outcomes [7,37]. This includes input from intensivists, gastroenterologists, interventional radiologists, infectious disease specialists, nutritionists, among others. We agree with Sosa et al [3] that it is the “combined experience of the entire team of pancreatic care providers”, and not necessarily the hospital volume, surgeon volume or surgeon experience that make the difference in peri-operative outcomes. We also believe that is feasible to foster the growth of a multidisciplinary support team in low-volume institutions.

**Implementation of centralization**

Although data accumulated to support centralization, there was reluctance to route patients to high-volume centers, even in the developed countries where data proved better outcomes [7,37]. This includes input from intensivists, gastroenterologists, interventional radiologists, infectious disease specialists, nutritionists, among others. We agree with Sosa et al [3] that it is the “combined experience of the entire team of pancreatic care providers”, and not necessarily the hospital volume, surgeon volume or surgeon experience that make the difference in peri-operative outcomes. We also believe that is feasible to foster the growth of a multidisciplinary support team in low-volume institutions.

**Negative effects of centralization**

Finally, there is existing data to show that healthcare inequity has developed in hospitals that adopted the centralization principle. There is clear data to show that patients are significantly less likely to have
Table 3 Proportion of pancreatico-duodenectomies performed outside of high-volume centers

| Author          | Country                           | PDs performed by low volume hospital, % | Average surgeon volume | Average hospital volume |
|-----------------|-----------------------------------|----------------------------------------|------------------------|------------------------|
| Sosa et al[3], 1998 | Maryland, United States           | 47.3                                   | 1 per year             | 1 per year             |
| Riall et al[17], 2007 | Texas, United States              | 36.7                                   | NR                     | < 5 PD per year        |
| Birkmeyer et al[5], 1999 | Medicare database, United States | > 50                                   | NR                     | < 2 PD per year        |
| Ho et al[7], 2003 | Florida and California, United States | 77                                      | NR                     | 10% in hospitals doing 1 PD per year |
| Bliss et al[24], 2014, For period < 2004 | Nationwide inpatient sample database, United States | 40.8 | NR | NR |
| Bliss et al[24], 2014, For period > 2011 | Nationwide inpatient sample database, United States | 26.9 | NR | NR |
| Glasgow et al[9], 1996 | California, United States        | 88                                     | NR                     | < 2 PD per year        |
| Fong et al[1], 2005 | National Medicare Database, United States | 89                                      | 1 per year             | 1 PD per year          |

PD: Pancreatico-duodenectomy; NR: Not reported.

PD in a high-volume center if they are non-white (Table 4)[3,16,17,24,39], female[17] or did not have private insurers (Table 5)[24]. Eppsteiner et al[35] also documented that across the United States, patients were significantly more likely to have their pancreatic resections by high-volume surgeons if they were male, white raced, and a resident of a high-income zip code.

CARIBBEAN EXPERIENCE

The age standardized incidence of pancreatic adenocarcinoma in the Caribbean is 4.4 per 100000 population[40]. However, only 3 of 17 Caribbean countries have populations > 200000 persons. Therefore, few patients develop peri-ampullary lesions and qualify for PD annually. Peri-ampullary malignancies remain the most common indication for PD in the Caribbean, but most patients are not able to access high-volume centers in developed countries because of travel restrictions, lack of social support, financial limitations and/or lack of health insurance. Therefore, local hospitals are often their only options for PD.

After three specialized HPB centers were established in the Caribbean in 2011, general surgeons readily gave up performing major hepatectomies but they have been reluctant to give up PDs. We previously reported that 98% of hepatectomies are now performed by subspeciality trained HPB surgeons[41], but a review of unpublished data from the same database between 2013 and 2020 showed that 80% of attempted PDs were performed by HPB teams (Table 6).

As a surrogate marker of technical expertise, we used the same database to tally the number patients who had PD attempted and those who had PDs completed. The HPB surgeons completed 94% of attempted PDs, but general surgeons performed palliative bypasses in all 18 cases. Schmidt et al[1] suggested that vein reconstruction was a surrogate marker for surgeon experience. In this database, HPB surgeons were more likely to perform vein reconstruction during PD compared to general surgeons (26% vs 0). This suggests that the specialty surgeons were experienced, although none were high-volume surgeons using conventional criteria in Table 1. Published data documented that only 12.8 PDs were performed annually at the busiest specialized HPB center in the Caribbean[42]. Nevertheless, we believe that outcomes can be improved using a modified centralization concept, with attention to the following five points.

Leadership

Surgical leaders must recognize that the concept of centralization is a significant deviation from “cultural norms” in the Caribbean and general surgeons are bound to resist this change. We must also recognize that it is not feasible to send all patients across the region to referral centers. Even if this was feasible, it would be undesirable because it would develop services in a handful of institutions but it would not be beneficial to the entire population at large.

Therefore, an astute leader could instead offer to operate at lower-volume centers assisted by general surgeons. In this way, they could identify and change hospital-based practices and processes. This has several potential advantages: better trained staff, diligence in care administration, development of critical care pathways and improved proficiency of the less experienced facility and their staff to care for...
Table 4 Patients undergoing pancreatico-duodenectomy at high-volume centers (%)

| Parameter | Data source | Whites, % | Non-whites, % | P      |
|-----------|-------------|-----------|---------------|--------|
| Sosa et al[13], 1998 | Non-federal facilities in Maryland, United States | 25.2 | 9.8 | < 0.001 |
| McPhee et al[16], 2007 | National Inpatient Sample Database, United States | 80 | 20 | NS |
| Bliss et al[14], 2014 | National Inpatient Sample Database, United States | 65.6 | 34.4 | 0.018 |
| Eppsteiner et al[15], 2009 | National Inpatient Sample Database, United States | 79.3 | 20.7 | NS |

PD: Pancreatico-duodenectomy; NS: Not specified.

Table 5 Patients undergoing pancreatico-duodenectomy with private insurance coverage (%)

| Parameter | Data source | High-volume center, % | Low-volume center, % | P   |
|-----------|-------------|-----------------------|----------------------|-----|
| Bliss et al[14], 2014 | 6144 patients undergoing PD | 43.7 | 36.9 | < 0.001 |

PD: Pancreatico-duodenectomy.

Table 6 A comparison of outcomes in 90 patients undergoing pancreatico-duodenectomy in a Caribbean centre

| Parameter | Sub-specialty surgeon, (%) | General surgeon, (%) | P       |
|-----------|----------------------------|----------------------|---------|
| Attempted PD | 72/90 (80)                 | 18 (20)              | < 0.0001² |
| Completed PD | 68/72 (94)                 | 0                    | < 0.0001⁶ |
| Portal vein resection/reconstruction | 19/72 (26) | 0 | 0.0103³ |

²Statistical analysis using Fishers Exact Test.
⁶Statistical analysis using Z-test for Proportions.
³Statistical analysis using Chi-square test.

PD: Pancreatico-duodenectomy.

Cawich SO et al. Whipple's operation

Critical patients. We agree with Pawlik et al[31], Billimora et al[8], Gasper et al[20], Hashimoto et al[43] and Ravaioli et al[55] that we should strive to identify specific elements of patient care in specialized hospitals that lead to better outcomes and introduce them in less-experienced facilities.

**Fostering team spirit**

We have already made the point that PDs are technically complex and unforgiving operations. Complications will occur once sufficient cases are attempted - and, regardless of surgeon skill and experience, it is the multidisciplinary team effort that will save patients. Therefore, it is important to pay attention to the pre- and post-operative care pathways.

Before selecting a patient for PD, there should be rigorous pre-operative evaluation[8,44,45], medical optimization[8], anaesthetic assessment[8,44] and tumour board discussion[46]. Mature surgeon judgment also has a large impact on the patient that makes it to the operating table. All of these factors affect peri-operative outcomes.

When complications develop in the post-operative phase, it is often not the surgeon who comes to the rescue. They rely on multidisciplinary support from a variety of specialties for around-the-clock emergency care[8,47-51]. It goes without saying that these services should be developed concurrently and we should strive for good interpersonal relationships across disciplines.

**Critical assessment of the healthcare environment**

It is clear that the healthcare environment in the Caribbean differs significantly from those in developed countries. We have provided data showing that local subspecialty surgeons are experienced, but they have repatriated to resource-poor settings with many challenges: scarce blood products, lack of readily available specialized equipment, high competition for ICU/HDU beds, an undersupply of consumables and infrequent operating lists.

One is forced to realize that the environment is not always conducive to observing best practice recommendations[41]. In order to maintain quality service delivery, surgeons must perform a critical appraisal of their local facility and understand the pitfalls in their environment. Tailored processes of care would then have to be devised that suit the local healthcare environment. We agree with Sosa et al...
Developing partnerships

While the traditional concept of centralization according to hospital volume or surgeon experience may not be practical in the Anglophone Caribbean, we have seen improved outcomes after introducing a partnership concept. In this concept, patients need not be channeled solely to referral centers. Instead, most Caribbean countries are sufficiently small for staff to move from referral centers to less experienced facilities, bringing with them experience, knowledge and select equipment for safe operations to be performed. Similarly, Ravaioli et al[52] published data to show that their institutions benefited from partnerships between high and low-volume facilities.

With this approach, we found that general surgeons still felt useful and were willing to cooperate with sub-specialists. They benefited because they received oversight from subspecialty surgeons, felt empowered to communicate about complications and increased their skillsets. Other authors have made similar suggestions to transfer mechanisms to improve outcomes into lower-volume hospitals where most patients receive their care[8,31,52].

Regular audit

Over the years that the HPB units have been implemented in the Caribbean setting, we have prioritized data collection because we recognize that this is the way to objectively evaluate our clinical practices. The value of this exercise ultimately lies in improvement in outcomes after PD for the population as a whole, but changes in outcomes will not be fully evident until regular audits are carried out. This is the only way to create tangible benefits for the healthcare system. Regular review of the data also allows us to better understand the challenges in the local healthcare system, ultimately facilitating the development of clinical care pathways and effective use of limited resources.

Knowledge of population based data

It is important for surgeons to be knowledgeable about the characteristics of the population they work with. For example, it has been shown that persons of Caribbean descent harbor greater-than expected HPB anatomic variations[53]. If a surgeon has not anticipated and/or identified these variants, they can be easily injured and create significant complications. An example is a replaced right hepatic artery coursing behind the pancreatic head. This is prone to injury during PD and can lead to hepatic ischemia and mortality. In Caribbean populations, a replaced right hepatic artery coursing behind the pancreatic head is present in 18% of unselected individuals - significantly greater than published reports in medical literature[53].

Ultimately, there seems to be emerging consensus in the recent medical literature that hospital volume, surgeon volume and hospital teaching status are only proxies for not-yet-fully understood processes of care delivery[52,54,55]. These vary between facilities, but include staffing level, tumour board meetings, surgeon skill, care pathways, available technology and support services. Instead of focusing on these proxies, physicians should focus on specific hospital-based outcomes data and find directed ways to improve the quality of care in your hospital despite volume, surgeon, teaching or financial status of the facility.

CONCLUSION

Despite low case volumes, cultural resistance to subspecialty care, financial barriers and resource-poor environments, we have been able to maintain acceptable short-term outcomes after PDs. We advocate developing an intimate knowledge of your health care system to identify processes that will facilitate good outcomes. In our setting we used a modified centralization concept, with attention to creating partnerships with experienced staff, fostering teamwork, appropriate staff training, development of care pathways, regular audits and knowledge of population-based data.

FOOTNOTES

Author contributions: Cawich SO, Naraynsingh V, Deshpande R and Shukla P designed and coordinated the study; Pearce NW, Deshpande R, Shukla and Naraynsingh V acquired and analyzed data; Cawich SO, Naraynsingh V, Deshpande R and Shukla P and Pearce NW interpreted the data; Cawich SO, Naraynsingh V, Deshpande R and Shukla P and Pearce NW wrote the manuscript; all authors approved the final version of the article.

Conflict-of-interest statement: All authors report no relevant conflict of interest for this article.

Open-Access: This article is an open-access article that was selected by an in-house editor and fully peer-reviewed by
REFERENCES

1. Schmidt CM, Turrini O, Parikh P, House MG, Zyromski NJ, Nakeeb A, Howard TJ, Pitt HA, Lillemoe KD. Effect of hospital volume, surgeon experience, and surgeon volume on patient outcomes after pancreaticoduodenectomy: a single-institution experience. Arch Surg 2010; 145: 634-640 [PMID: 20644125 DOI: 10.1001/archsurg.2010.118]

2. Lieberman MD, Kilburn H, Lindsey M, Brennan MF. Relation of perioperative deaths to hospital volume among patients undergoing pancreatic resection for malignancy. Ann Surg 1995; 222: 638-645 [PMID: 7487211 DOI: 10.1097/00000658-199511000-00006]

3. Sosa JA, Bowman HM, Gordon TA, Bass EB, Yeo CJ, Lillenme K, Cameron JL. Importance of hospital volume in the overall management of pancreatic cancer. Ann Surg 1998; 228: 429-438 [PMID: 9742926 DOI: 10.1097/00000658-199809000-00016]

4. Fong Y, Gonen M, Rubin D, Radzynier M, Brennan MF. Long-term survival is superior after resection in cancer in high-volume centers. Ann Surg 2005; 242: 540-4; discussion 544 [PMID: 16192814 DOI: 10.1097/01.sla.0000188462.00249.36]

5. Birkmeyer JD, Finlayson SR, Tosteson AN, Sharp SM, Warshaw AL, Fisher ES. Effect of hospital volume on in-hospital mortality with pancreaticoduodenectomy. Surgery 1999; 125: 250-256 [PMID: 10076608 DOI: 10.1067/s0033-6609(99)70234-5]

6. Kotwall CA, Maxwell JG, Brinker CC, Koch GG, Covington DL. National estimates of mortality rates for radical pancreatectomy in 25,000 patients. Ann Surg Oncol 2002; 9: 847-854 [PMID: 12417505 DOI: 10.1007/BF02557520]

7. Ho V, Heslin MJ. Effect of hospital volume and experience on in-hospital mortality for pancreaticoduodenectomy. Ann Surg 2003; 237: 509-514 [PMID: 12677147 DOI: 10.1097/01.sla.0000059981.13160.97]

8. Billmoria KY, Bentrem DJ, Feinglass JM, Stewart AK, Winchester DP, Talamonti MS, Ko CY. Directing surgical quality improvement initiatives: comparison of perioperative mortality and long-term survival for cancer surgery. J Clin Oncol 2008; 26: 4626-4633 [PMID: 18574159 DOI: 10.1200/JCO.2007.11.0024]

9. Glasgow RE, Mulvihill SJ. Hospital volume influences outcome in patients undergoing pancreatic resection for cancer. West J Med 1996; 165: 294-300 [PMID: 8993200]

10. La Torre M, Nigri G, Ferrari L, Cosenza G, Ravaiol M, Ramacciato G. Hospital volume, margin status, and long-term survival after pancreaticoduodenectomy for pancreatic adenocarcinoma. Am Surg 2012; 78: 225-229 [PMID: 22369344 DOI: 10.1177/000313481207800243]

11. Nathan H, Cameron JL, Choti MA, Schullick RD, Pawlik TM. The volume-outcomes effect in hepato-pancreato-biliary surgery: hospital versus surgeon contributions and specificity of the relationship. J Am Coll Surg 2009; 208: 528-538 [PMID: 19476786 DOI: 10.1016/j.jamcollsurg.2009.01.007]

12. Gouma DJ, van Geenen RC, van Gulik TM, de Haan RJ, de Wit LT, Busch OR, Obertop H. Rates of complications and death after pancreaticoduodenectomy: risk factors and the impact of hospital volume. Ann Surg 2000; 232: 786-795 [PMID: 11088073 DOI: 10.1097/00000658-200012000-00007]

13. Nordback L, Parviainen M, Räty S, Kuivaniæ H, Sand J. Resection of the head of the pancreas in Finland: effects of hospital and surgeon on short-term and long-term results. Scand J Gastroenterol 2002; 37: 1454-1460 [PMID: 12523597 DOI: 10.1080/036555202762671350]

14. Finlayson EV, Birkmeyer JD. Effects of hospital volume on life expectancy after selected cancer operations in older adults: a decision analysis. J Am Coll Surg 2003; 196: 410-417 [PMID: 12648693 DOI: 10.1016/j.tsci.2003.02.01753-2]

15. van Heek NT, Kuhlmann KF, Scholten RJ, de Castro SM, Busch OR, van Gulik TM, Obertop H, Gouma DJ. Hospital volume and mortality after pancreatic resection: a systematic review and an evaluation of intervention in the Netherlands. Arch Surg 2005; 140: 781-788, discussion 788 [PMID: 16327488 DOI: 10.1001/archsurg.2005.19]

16. McPhee JT, Hill JS, Whalen GF, Zayarakun M, Litwin DE, Sullivan ME, Anderson FA, Tseng JF. Perioperative mortality for pancreatic resection: a national perspective. Ann Surg 2007; 246: 246-253 [PMID: 17667503 DOI: 10.1097/01.sla.0000259933.17350.3a]

17. Riall TS, Eschbach KA, Townsend CM Jr, Nealon WH, Freeman JL, Goodwin JS. Trends and disparities in regionalization of pancreatic resection. J Gastrointest Surg 2007; 11: 1242-51; discussion 1251 [PMID: 17694419 DOI: 10.1007/s11605-007-0245-5]

18. Meguid RA, Abuja N, Chang DC. What constitutes a “high-volume” hospital for pancreatic resection? J Am Coll Surg 2008; 206: 622.e1-622.e9 [PMID: 18387466 DOI: 10.1016/j.jamcollsurg.2007.11.011]

19. Balzano G, Zerbi A, Capretti G, Rocchetti S, Capitanio V, Di Carlo V. Effect of hospital volume on outcome of
pancreatoduodenectomy in Italy. Br J Surg 2008; 95: 357-362 [PMID: 17933001 DOI: 10.1002/bjs.5982]

20 Gaster WJ, Glidden DV, Jin C, Way LW, Patti MG. Has recognition of the relationship between mortality rates and hospital volume for major cancer surgery in California made a difference? Ann Surg 2009; 250: 472-483 [PMID: 19730178 DOI: 10.1097/SLA.0b013e3181b47c79]

21 Teh SH, Diggs BS, Deveney CW, Sheppard BC. Patient and hospital characteristics on the variance of perioperative outcomes for pancreatic resection in the United States: a plea for outcome-based and not volume-based referral guidelines. Arch Surg 2009; 144: 713-721 [PMID: 19687371 DOI: 10.1001/archsurg.2009.67]

22 Gooolker GA, van Gijn W, Wouters MW, Post PN, van de Velde CJ, Tolloenar RA; Signalling Committee Cancer of the Dutch Cancer Society. Systematic review and meta-analysis of the volume-outcome relationship in pancreatic surgery. Br J Surg 2011; 98: 485-494 [PMID: 21500187 DOI: 10.1002/bjs.7413]

23 Abfsasser G, Kittner J, Eisold S, Klar E. Volume-outcome relationship in pancreatic surgery: the situation in Germany. Surgery 2012; 152: S50-S55 [PMID: 22763260 DOI: 10.1016/j.surg.2012.05.011]

24 Bliss LA, Yang CJ, Chau Z, Ng SC, McFadden DW, Kent TS, Moser AJ, Callery MP, Tseng JF. Patient selection and the volume effect in pancreatic surgery: unequal benefits? HPB (Oxford) 2014; 16: 899-906 [PMID: 24905343 DOI: 10.1111/hpb.12283]

25 Derogar M, Blombrek J, Sadr-Azodi O. Hospital teaching status and volume related to mortality after pancreatic cancer surgery in a national cohort. Br J Surg 2015; 102: 548-57; discussion 557 [PMID: 25711855 DOI: 10.1002/bjs.9754]

26 Hata T, Motoi F, Ishida M, Naitoh T, Katayose Y, Egawa S, Unno M. Effect of Hospital Volume on Surgical Outcomes After Pancreatoduodenectomy: A Systematic Review and Meta-analysis. Ann Surg 2016; 263: 664-672 [PMID: 26636243 DOI: 10.1097/SLA.0000000000001457]

27 Briceno P, Hulton J, Shridhar R, Meredith K. Pancreatic Resection at High Volume Centers Improves Survival. HPB 2017; S17: 131 [DOI: 10.1016/j.hpb.2017.02.384]

28 El Amrani M, Clement G, Lenne X, Farges O, Delpero JR, Theis D, Pruvot FR, Trruant S. Failure-to-rescue in Patients Undergoing Pancreatectomy: Is Hospital Volume a Standard for Quality Improvement Programs? Ann Surg 2018; 268: 799-807 [PMID: 30048329 DOI: 10.1097/SLA.0000000000002945]

29 Krautz C, Nimptsch U, Weber GF, Grützmann R. Effect of Hospital Volume on In-hospital Morbidity and Mortality Following Pancreatic Surgery in Germany. Ann Surg 2018; 267: 411-417 [PMID: 28379871 DOI: 10.1097/SLA.0000000000002484]

30 Balzano G, Guarneri G, Pecorelli N, Paiella S, Rancoita PMV, Bassi C, Falconi M. Modelling centralization of pancreatic surgery in a nationwide analysis. Br J Surg 2020; 107: 1510-1519 [PMID: 32592514 DOI: 10.1002/bjs.11716]

31 Pawlik TM, Tanabe KK. Is it ethical to send patients to low-volume hospitals for cancer surgery? Virtual Mentor 2007; 9: 44-47 [PMID: 23217670 DOI: 10.1016/j.vmtl.2007.01.001]

32 Hillner BE, Smith TJ, Desch CE. Hospital and physician volume or specialization and outcomes in cancer treatment: importance in quality of cancer care. J Clin Oncol 2000; 18: 2327-2340 [PMID: 10829054 DOI: 10.1200/JCO.2000.18.11.2327]

33 Hodgson DC, Zhang W, Zaslavsky AM, Fuchs CS, Wright WE, Ayanian JZ. Relation of hospital volume to colostomy rates and survival for patients with rectal cancer. J Natl Cancer Inst 2003; 95: 708-716 [PMID: 12759388 DOI: 10.1093/jnci/95.7.708]

34 Riall TS, Nealon WH, Goodwin JS, Townsend CM Jr, Freeman JL. Outcomes following pancreatic resection: variability among high-volume providers. Surgery 2008; 144: 133-140 [PMID: 18656618 DOI: 10.1016/j.surg.2008.03.041]

35 Eppsteiner RW, Ciocesker NG, McPhee JT, Tseng JF, Shah SA. Surgeon volume impacts hospital mortality for pancreatic resection. Ann Surg 2009; 249: 635-640 [PMID: 19302225 DOI: 10.1097/SLA.0b013e31819e0df5]

36 Tseng JF, Pisters PW, Lee JE, Wang H, Gomez HF, Sun CC, Evans DB. The learning curve in pancreatic surgery. Surgery 2007; 141: 694-701 [PMID: 17511155 DOI: 10.1016/j.surg.2007.04.001]

37 Bouvet M. Comment on the Effect of Hospital Volume, Surgeon Experience, and Surgeon Volume on Patient Outcomes After Pancreatoduodenectomy. Arch Surg 2010; 145: 640

38 Birchmeyer JD. High-risk surgery—follow the crowd. JAMA 2000; 283: 1191-1193 [PMID: 10703783 DOI: 10.1001/jama.283.9.1191]

39 Goodney PP, Stukel TA, Lucas FL, Finlayson EV, Birkmeyer JD. Hospital volume, length of stay, and readmission rates in high-risk surgery. Ann Surg 2003; 238: 161-167 [PMID: 12894006 DOI: 10.1097/01.sla.0000081094.66659.e3]

40 Rawla P, Sunkara T, Gaduputi V. Epidemiology of Pancreatic Cancer: Global Trends, Etiology and Risk Factors. World J Oncol 2019; 10: 10-27 [PMID: 30834048 DOI: 10.14740/wjon1166]

41 Cawich SO, Maharaj R, Narayansingh V, Pearce N, Francis W, Bonadie KO, Thomas DA. Clinical outcomes after major hepatectomy are acceptable in low-volume centers in the Caribbean. World J Hepatol 2019; 11: 199-207 [PMID: 30820269 DOI: 10.4254/wjh.v11.i2.199]

42 Cawich SO, Kluger MD, Francis W, Deshpande RR, Mohammed F, Bonadie KO, Thomas DA, Pearce NW, Schrope BA. Review of minimally invasive pancreatic surgery and opinion on its incorporation into low volume and resource poor centres. World J Gastrin Endosc Surg 2021; 13: 1122-1135 [PMID: 34754382 DOI: 10.4240/wjges.v13.i10.1122]

43 Hashimoto DA, Bababekov YJ, Mehtsun WT, Stapleton SM, Warshaw AL, Lillemoe KD, Chang DC, Vageli PA. Is Annual Volume Enough? Ann Surg 2017; 266: 603-609 [PMID: 28692470 DOI: 10.1097/SLA.0000000000002377]

44 Birchmeyer JD, Sun Y, Goldfadan A, Birkmeyer NJ, Stukel TA. Volume and process of care in high-risk cancer surgery. Cancer 2006; 106: 2476-2481 [PMID: 16634089 DOI: 10.1002/cncr.21885]

45 Chassin MR. Achieving and sustaining improved quality: lessons from New York State and cardiac surgery. Health Aff (Millwood) 2002; 21: 40-51 [PMID: 12117152 DOI: 10.1377/hastf.21.4.40]

46 Hoech RS, Rijser CJ, Winters S, Stitt L, Hogg ME, Bartlett DL, Lee KK, Panici A, Ohr JP, Gorantla VC, Krishnamurthy A, Rhee JC, Bahary N, Olson AC, Burton S, Ellsworth SG, Sivika A, McGrath K, Khalid A, Fasanelka L, Chennat J, Brand RE, Das R, Sarkaria R, Singh R, Zeh JJ, Zureikat AH. A Pancreatic Cancer Multidisciplinary Clinic Eliminates Socioeconomic Disparities in Treatment and Improves Survival. Ann Surg Oncol 2021; 28: 2438-2446 [PMID: 33523364 DOI: 10.1245/s10434-021-09594-8]
47 Pronovost PJ, Angus DC, Dorman T, Robinson KA, Dremsizov TT, Young TL. Physician staffing patterns and clinical outcomes in critically ill patients: a systematic review. *JAMA* 2002; 288: 2151-2162 [PMID: 12413375 DOI: 10.1001/jama.288.17.2151]

48 Hartz AJ, Krakauer H, Kuhn EM, Young M, Jacobsen SJ, Gay G, Muenz L, Katzoff M, Bailey RC, Rimm AA. Hospital characteristics and mortality rates. *N Engl J Med* 1989; 321: 1720-1725 [PMID: 2594031 DOI: 10.1056/nejm198912213212506]

49 Alken LH, Clarke SP, Cheung RB, Sloane DM, Silber JH. Educational levels of hospital nurses and surgical patient mortality. *JAMA* 2003; 290: 1617-1623 [PMID: 14506121 DOI: 10.1001/jama.290.12.1617]

50 Traverso LW, Shinchi H, Low DE. Useful benchmarks to evaluate outcomes after esophagectomy and pancreaticoduodenectomy. *Am J Surg* 2004; 187: 604-608 [PMID: 15135674 DOI: 10.1016/j.amjsurg.2004.01.009]

51 Luchette F, Kelly B, Davis K, Johanningman J, Heink N, James L, Ottaway M, Hurst J. Impact of the in-house trauma surgeon on initial patient care, outcome, and cost. *J Trauma* 1997; 42: 490-5; discussion 495 [PMID: 9095117 DOI: 10.1097/00005373-199703000-00017]

52 Ravaioli M, Pinna AD, Francioni G, Montorsi M, Veneroni L, Grazi GL, Palini GM, Gavazzi F, Stacchini G, Ridolfi C, Serenari M, Zerbi A. A partnership model between high- and low-volume hospitals to improve results in hepatobiliary pancreatic surgery. *Ann Surg* 2014; 260: 871-5; discussion 875 [PMID: 25243551 DOI: 10.1097/SLA.0000000000000975]

53 Cawich SO, Sinanan A, Gosein M, Pearce N, Deshpande R, Mohammed F, Narayansingh V, Fortune M, Rampersad F. An Investigative Study of Hepatic Arterial Anomalies in a West Indian Population. *Radiol Res Pract* 2021; 2021: 9201162 [PMID: 34691781 DOI: 10.1155/2021/9201162]

54 Finlayson EV, Goodney PP, Birkmeyer JD. Hospital volume and operative mortality in cancer surgery: a national study. *Arch Surg* 2003; 138: 721-5; discussion 726 [PMID: 12860752 DOI: 10.1001/archsurg.138.7.721]

55 Porter GA, Pisters PW, Mansyur C, Bisanz A, Reyna K, Stanford P, Lee JE, Evans DB. Cost and utilization impact of a clinical pathway for patients undergoing pancreaticoduodenectomy. *Ann Surg Oncol* 2000; 7: 484-489 [PMID: 10947015 DOI: 10.1007/s10434-000-0484-0]

Cawich SO et al. Whipple’s operation
