
Special Article

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Anaesthesia in Barbados

Purpose: To describe the anaesthesia services in Barbados; to present the major challenges confronting the Anaesthesia Department of the government-owned Queen Elizabeth Hospital (QEH); and to describe the Department's approaches to optimise safety and cost-effectiveness of anaesthesia at QEH.

Source of Information: Authors (KBS, HSLM, RAH), who collectively provided more than 50 yr of anaesthesia at QEH; the Dean (ERW) of the University of West Indies Medical School (Barbados campus); archives of Barbados; and records of QEH.

Principal findings: The government of Barbados provides modern health care services to all of its citizens, primarily at QEH. Barbados, however, has tight financial constraints, infrastructural limitations, and a bureaucratic administration that predispose QEH's Anaesthesia Department to unexpected depletions of drugs and disposable supplies, sporadic shortages of personnel and functioning equipment, and occasional quality assurance problems. To deal with such problems, the Anaesthesia Department has implemented several pro-active measures: establishing an audit system to prevent depletion of imported drugs and supplies; training local personnel to maintain equipment; purchasing an oxygen concentrator to reduce oxygen costs; decreasing nitrous oxide use (expensive in Barbados); and initiating its own quality and safety standards.

Conclusion: Continuous delivery of high quality, cost-effective anaesthesia care requires thoughtful planning by administrators and judicious resource allocations. Health care administrators and clinical departments need to work together closely to establish a framework that enables departments to play a major role in determining how the institution's limited financial resources are best allocated to meet the departmental priorities.

Objectif : Décrire l'organisation de l'anesthésie à la Barbade ; présenter les problèmes considérables auxquels doit faire face le département d'anesthésie de l'hôpital d'état Queen Elizabeth (QEH) et décrire les efforts du département pour optimiser la sécurité et l'efficacité en fonction des coûts .

Source de l'information : Les auteurs (KBS, HSLM, RAH) qui ont collectivement fourni plus de 50 ans d'anesthésie au QEH ; le doyen de la faculté de médecine des Antilles (campus de la Barbade) ; les archives de la Barbade ; les dossiers du QEH.

Principales constatations : Le gouvernement de la Barbade procure des services sanitaires modernes à tous ses citoyens, principalement au QEH. La Barbade subit toutefois des contraintes financières très sévères, des limitations dans son infrastructure et une bureaucratie qui prédispose le département d'anesthésie du QEH à des pénuries imprévisibles de médicaments et de matériel jetable, à l'absentéisme du personnel et au manque d'équipement sporadique, et à des problèmes occasionnels d'assurance-qualité. Pour régler ces genres de problèmes, le département d'anesthésie a mis en vigueur plusieurs mesures simultanées ; l'établissement d'un système de comptabilité pour prévenir les pénuries de médicaments et du matériel importés ; la formation de personnel pour la maintenance de l'équipement ; l'achat d'un concentrateur pour réduire le coût de l'oxygène ; la rationnement du protoxyde d'azote (cher à la Barbade) ; et le mise en vigueur de ses propres standards de qualité et de sécurité.

Conclusion : La prestation continue de soins anesthésique efficients et de haute qualité requiert une planification soignée et l'allocation judicieuse de ressources. Les administrateurs en soins de santé et les départements cliniques doivent travailler de concert pour établir un encadrement permettant aux départements de jouer un rôle majeur dans l'allocation de ressources financières limitées en tenant compte des priorités établies par les départements.

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Accepted for publication January 25, 1997.

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General information

Most island-nations of the Caribbean were colonies of England, France, Spain or the Netherlands. Such associations have influenced the culture, language, and lifestyle of the local populations. French- and Dutch-speaking nations, for example, remain politically linked to their mother countries and have subsidised health care systems, affording them a quality of care similar to that of their respective mother countries. In contrast, most of the English-speaking island nations, whether independent or still dependent on Great Britain, are responsible for administering their own health care systems. Thus, among Caribbean islands, the quality of medical services is variable, being highly dependent upon political factors and the islands' economies.

Barbados is an English-speaking island nation in the Caribbean (Figure). The island has approximately 250,000 inhabitants and hosts 900,000 vacationers each year (Barbados Statistical Service, 1995). It has a well-developed network of roads, modern airport facilities and harbours, and a modern telecommunication

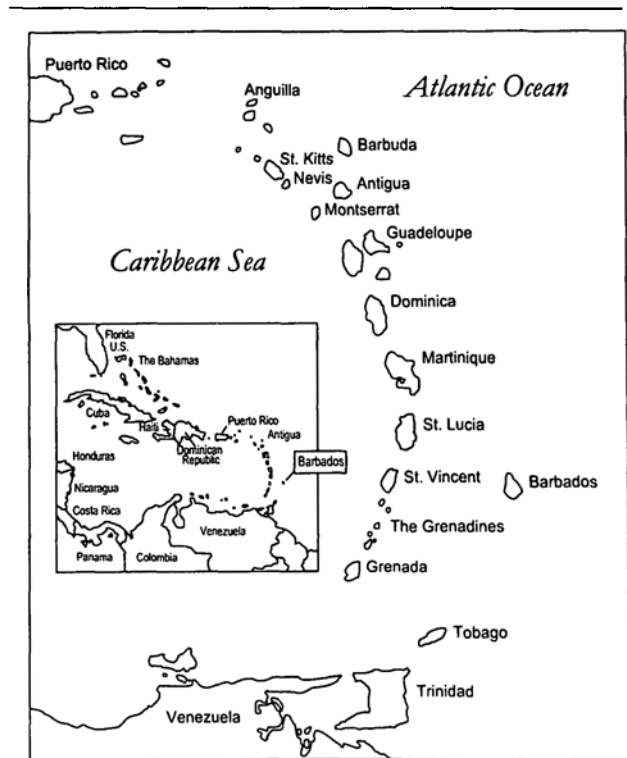


FIGURE Location of Barbados in relation to other Caribbean islands. Insert. Larger geographical area is shown including Caribbean islands: Barbados is highlighted.

system. Its health services are similar to those in developed countries,¹ due, in part, to an effective system of public health (maintenance of a safe supply of drinking water, comprehensive child immunisation programme), a high literacy rate (98%), and annual health expenditures of 14–18% of the Gross Domestic Product (GDP) since 1966, when Barbados gained independence from Great Britain.² Major medical services on the island are provided at the government-owned Queen Elizabeth Hospital (QEH), a 650-bed teaching affiliate of the University of West Indies (UWI) and a referral centre for several Caribbean countries.

Health care system in Barbados

The government of Barbados offers health care to all its citizens and residents without supplemental charges. Primary care and various speciality services (obstetrics/gynaecology, paediatric care) are delivered through a system of eight polyclinics. The Queen Elizabeth Hospital (QEH), located near Bridgetown, the capital city, in the South-western quadrant of the island, provides most of the secondary and tertiary care and all emergency medical and surgical services in Barbados. A psychiatric hospital within 10 miles of QEH administers

all routine and emergency psychiatric care. The island also has five geriatric hospitals to serve the needs of chronically ill and debilitated elderly patients.

Although a majority of residents utilise the public health care system, private medical care is also available in Barbados. The private care system caters to visitors, affluent locals, and others who purchase medical insurance or receive such insurance from their employers. Private practice clinics are dispersed throughout Barbados, but the island has only one exclusively private inpatient hospital (Bayview), which is located within three miles of Bridgetown. Bayview has 30 beds, and is the site of 1500 operative procedures annually; it does not offer intensive care services. The Heritage Clinic also performs 300 ambulatory surgical cases per year. Bayview and Heritage together employ four full time/part-time anaesthetists to provide anaesthetic services.

Another important provider of private care is the QEH, which reserves 50 private beds for the departments of surgery, medicine, ophthalmology and obstetrics and gynaecology. Private patients pay for all their medical expenses, including physician's fees. Queen Elizabeth Hospital also has a semi-private category, wherein patients select and pay their physicians, but are managed on the public wards. The QEH charges both private and semi-private patients a pre-determined fee based on the type of surgery, along with a per diem for use of ward facilities (semi-private rates are lower than private rates).

The Queen Elizabeth Hospital

As a tertiary referral centre, QEH serves approximately 1,000,000 people in the English-speaking Caribbean from Anguilla in the north to Grenada in the south. The QEH also serves the 900,000 tourists per year who come primarily from North America and Europe (Barbados Statistical Service 1995). Vacationers account for 2.1% of annual hospital admissions;³ trauma and cardiovascular disease are the main reason for these hospitalisations. Seven percent of visitor admissions are for Intensive Care Unit (ICU) services versus 0.15% for Barbadians.³ The average length of stay at QEH is 11.7 days for visitors compared with 7.0 days for the local population.³

All major medical and surgical specialities, including obstetrics (4,000 deliveries per year), are represented at QEH. The 6,000–8,000 operations performed annually include complex procedures such as neonatal surgery (tracheo-oesophageal fistula, diaphragmatic hernia, omphalocele and meningocele etc.) and cardiac operations. The open heart surgery programme, established in 1994, serves the organisation of Eastern Caribbean countries, includ-

ing Barbados. To date, approximately 120 cardiopulmonary bypass procedures have been successfully performed (mortality rate <3%). The success of this surgical programme has led to plans to offer interventional cardiology services in 1997.

The only site on Barbados that provides intensive care services (ICU) is QEH. The Hospital has three ICUs: surgical (cardiac and non-cardiac sections), medical and neonatal. The medical ICU was established in the mid-1970s, while the surgical and neonatal units were developed in 1991 with assistance from the World Bank (capital investment). The Varieties Club International is currently funding the construction of a fourth unit, for paediatrics (including paediatric cardiac surgery).

Indeed, privatisation of certain components of the health care system, as has occurred at QEH, has been essential to provide the capital to support medical advances in Barbados. The cardiac surgical programme at QEH, for example, could not have been established without an effective integration of public and private sectors (i.e., companies providing medical insurance). All parties involved in this joint venture are continuously evaluating the cost-effectiveness of providing complex cardiac services in Barbados.

History

Historical tribute

It seems proper to begin this history of anaesthesia with tributes to Drs. Henry Boyle and Wesley Bourne – two eminent anaesthetists from Barbados.

Henry Edmund Gaskin Boyle OBE, FRCS

Henry Edmund Gaskin Boyle was born in Barbados on April 2, 1875.⁴ He graduated from Harrison College and then left the island to attend medical school at St. Bartholomew's in London, England.⁵ After graduating in 1901, he was appointed junior resident anaesthetist at St. Bartholomew's. His strong interest in inhalation anaesthesia prompted him to attend a demonstration of Gwathmey's nitrous oxide-oxygen-ether machine in 1913.^{6,7} So impressed was Boyle with the potential of this machine that he persuaded his hospital's administrators to import one from the United States; it was the first to arrive in England.^{6,8} Boyle soon discovered that this machine had mechanical defects; of greatest concern was leakage at the gas union. Thus, in 1917, Boyle built the first British version of the nitrous oxide-oxygen-ether delivery system.^{6,9} Boyle's machine eventually became a world-wide standard for the administration of inhalational anaesthesia.⁶ Its basic design has survived

for over three-quarters of a century, albeit with modifications dictated by technological innovation.

Boyle played an active role in establishing scholarly standards in anaesthesia. He served on the editorial board of the *British Journal of Anaesthesia* during its initial publications in 1923.⁹ Boyle was also a founding member of the Association of Anaesthetists of Great Britain (established in 1932) and was one of the initial examiners for the Diploma of Anaesthetics in England.^{9,10} Eventually, Boyle's name became inextricably linked with "anaesthesia." Nonetheless, financial success eluded Boyle; he never profited from the invention of his machine and was impoverished at the time of his death on October 15, 1941.^{6,9}

*Wesley Bourne MD, CM, MSc, FRCPC, FICA, DA,
(RCP and S, Eng), FACA, FFARCS*

Wesley Bourne was born in Barbados on April 24, 1886.¹¹ He received his secondary education at the Lodge School before leaving the island to attend medical school at McGill University in Montréal, Canada. After graduating in 1911, Bourne joined the faculty at McGill, where he immersed himself in basic pharmacology research, attempting to elucidate the mechanism of anaesthesia drugs.¹² He was a highly regarded scientist and a prolific writer of more than 110 scientific publications.^{12,13}

During his career, Bourne accumulated an impressive list of achievements and honours.¹²⁻¹⁵ On two separate occasions, he served as president of the International Anesthesia Society (1925 and 1940). When the anaesthesia section of the British Medical Association was established, Bourne served as its first vice president. The Royal Society of Medicine honoured Bourne in 1935 by selecting him as the first recipient of the Hickman medal. In 1942, the American Society of Anesthesiologists elected Bourne as its president, making him the only non-American to serve in this capacity. In 1945, Bourne founded, and was the first chairman of, McGill University's Department of Anaesthesia. He was the originator of McGill's Diploma Course in Anaesthesia. Bourne is also credited with introducing the Greek phrase "Katheudontas Pavateroumen" ("we watch closely those who sleep"), which was ultimately adopted as the motto of the Canadian Anaesthetists Society.¹⁵

A powerful testimony to Bourne's genius and professional stature was his ability to meld the French- and English-speaking anaesthetists of Canada into one cohesive body. Recognising this, and many other of Bourne's important contributions to anaesthesia, the Canadian Anaesthetists Society, in 1962, conferred its highest honour upon Bourne, the Gold Medal.¹⁴

Historical perspective: Anaesthesia Department

It is unclear whether Boyle or Bourne influenced the development of anaesthesia in Barbados, since neither practised on the island. The first anaesthesia services were provided by a general practitioner, Dr. Basil Skinner, and two assistants, under the auspices of the Department of Surgery in the late 1940s. Realising the importance of formal training in anaesthesia, Skinner attended McGill University's Department of Anaesthesia for further training. He returned to Barbados in 1956 to establish the first Anaesthesia Department and to become its first chairman. Skinner's other contributions include the development of the first Post Anaesthesia Care Unit (PACU) in Barbados in 1964 and the invention of a sterilizable, soft and flexible, nylon epidural cannula (with Portland Plastics Ltd., Kent, England).¹⁶

Skinner left Barbados in 1966 to practice anaesthesia in Alberta, Canada, but he returned to Barbados in 1978 as a senior member of the Department. When he retired in 1984 to settle in Vancouver Island, Canada, he was already acknowledged as the "father of anaesthesia" in Barbados.

Anaesthesia training programme

The University of West Indies School of Medicine (UWI), established in 1948 in Jamaica, has additional campuses in Barbados and Trinidad. In 1967, the Faculty of Medical Sciences teaching programme was started in Barbados at the Queen Elizabeth Hospital as part of the Eastern Caribbean Medical Scheme. In 1976, Barbados began offering clinical training to students in the final two years of the MBBS degree programme. Also in 1976, Barbados established a one-year diploma programme in anaesthesia (DA); this was an extension of the DA programme of UWI, developed in Jamaica during the mid-1960's, to increase the availability of anaesthetists in the eastern Caribbean region. (DA's serve as specialists in private practice and as registrars in public hospitals.) In 1984, Barbados introduced a four-year post-graduate degree programme (DM) to complement the Jamaican DM programme established in the 1970s. The DM programme prepares trainees to become senior registrars and eventually, consultants, after three years of post-DM work experience.

Unfortunately, both DA and DM programmes have lacked a steady influx of trainees: in some years no residents entered the programmes in Barbados. Over 20 yr, there were 23 graduates of the DA programme: two completed the DM (one is a consultant cardiac anaesthetist and the other is a senior registrar at QEH): four became private practitioners in Barbados: 12 emigrated to practice in the USA, Canada, Great Britain or India: and five no longer practice anaesthesia. Thus, approximately 75% of

Barbados-trained DAs have chosen not to practice anaesthesia in the Caribbean. Possible explanations for this include: uncertainties about available consultant positions, the limited number of private practice opportunities, the desire for additional training in a developed country, or the lure of more promising employment abroad.

The increasing complexity of medical care in recent times has led the UWI to discontinue all diploma programmes (including the DA) in lieu of DM programmes. Candidates in Barbados' DM programme are headquartered at the QEH, but spend approximately 25% of their clinical time at other approved sites, including the University Hospital in Jamaica.

The UWI (Barbados) also offers supplemental training (elective rotations) for residents from Canada, Germany and the United States, affording them perspectives on anaesthesia in a developing nation along with an opportunity to strengthen their clinical abilities. Salaries for these residents are typically provided by the resident's training programme. The government of Barbados provides supplemental stipends of US\$1500 per month. While the Anaesthesia Department of QEH enthusiastically welcomes overseas residents, it does not depend upon them to provide clinical anaesthesia.

Anaesthesia at Queen Elizabeth Hospital

Anaesthesia personnel

Barbados has no nurse anaesthetists (a policy decision made by the department in the mid-1970s), although each operating room (OR) does have a designated anaesthetic aide/paramedic to assist anaesthetists. Anaesthesia services are provided by four attendings (consultants), eight senior registrars/junior registrars, and a variable number of senior house officers (sometimes none). Of the consultants, two graduated with DA degrees from UWI (Jamaica) and completed fellowships in Great Britain, one completed a DM in Barbados, and one was fully trained in India as a consultant anaesthetist (University of Madras, India). Only one of the eight senior registrars at QEH was trained in the Caribbean.

Consultants provide out-of-hospital coverage during weekends and evenings. Two junior registrars/senior registrars are available for after-hour emergency OR and ICU care. Technically, junior staff are not required to stay in the hospital, but they invariably remain on the premises, owing to the busy after-hours workload at the QEH.

The average annual income of a consultant, including the fee-for-service arrangement at QEH, is approximately US \$70,000. A senior registrar typically earns US \$55,000. Consultants may supplement their income by moonlighting at the private hospitals, whereas senior registrars are not allowed to work at sites other than QEH.

Anaesthesia techniques and services

The approach to anaesthesia is similar to that in North America and the United Kingdom. General anaesthesia has been administered for most operations, but regional anaesthesia is becoming more popular. Pre-emptive analgesia (pre-incision infiltration at surgical sites with bupivacaine 0.25%) is commonly provided, especially for paediatric ambulatory procedures. As a result, paediatric patients receiving inhalational anaesthesia often do not require intraoperative or postoperative opioids.

The Anaesthesia Department plays an important role in the ICUs. The Department provides consultation services on the respiratory care of patients in both the neonatal and medical intensive care units. (It had managed respiratory care of neonates until 1991, when QEH began to employ neonatologists.) The Department is also the sole director of the non-cardiac surgical unit, and it jointly directs (with cardiac surgery and cardiology) the cardiac section.

The Department does not provide obstetric analgesia services. In addition, it lacks a formal pain management service. Nonetheless, there is a consultant anaesthetist with a special interest in pain to address chronic pain problems. Anaesthetists treat postoperative pain until patients are discharged from the PACU; thereafter, pain management is provided by the surgical team.

Concerns of the Anaesthesia Department

The Anaesthesia Department has continued to evolve and expand to meet the needs of growing surgical services (e.g., cardiac surgery) and intensive care programmes at QEH. During growth phases, the Department has had to struggle with limitations related to personnel, equipment, supplies and budgets (Table).

Staffing concerns

Not infrequently, the Department becomes critically short-staffed, owing to unanticipated departures of anaesthesia personnel. Replacement of personnel is difficult because of a paucity of local DMs, and an inability to recruit local DAs who prefer private practice (more lucrative, less demanding positions than at QEH). Thus, the Department must often obtain anaesthetists (particularly at junior staff levels) from outside the Caribbean region to fill vacancies. This is a more prolonged process than recruiting local anaesthetists, as it involves cumbersome immigration procedures and poses additional financial burdens on an already strained health care bureaucracy (QEH is required to pay transportation and moving expenses).

Occasionally, workloads exceed the capacity of remaining staff to provide services safely, leading to post-

TABLE Concerns of an anaesthesia department in a small developing country

<i>Problems Encountered</i>	<i>Causes</i>	<i>Solution/Recommendation</i>
Sporadic shortages in anaesthesia staffing	Bureaucratic recruitment process Local shortage of trained anaesthesia personnel	<i>Encourage health administration to accelerate recruitment process of personnel from overseas</i> <i>Encourage and attract local medical graduates to specialise in anaesthesia</i>
Failure of medical gas pipelines system	No regulatory body to mandate periodic inspection and maintenance	Departments of Anaesthesia and Engineering established their own policies and regulations
High cost of inhalation anaesthetics, particularly nitrous oxide	Nitrous oxide is expensive and not produced locally, needs to be imported from overseas High cost of potent vapour anaesthetics	Oxygen/air substituted for nitrous oxide/oxygen during general anaesthesia. Use of low fresh gas flows often with closed circuit anaesthesia
Sporadic shortage of anaesthesia drugs and disposable items	Long procurement intervals	Determined consumption rates via audit/survey Placed purchase orders well in advance of need <i>Encourage administration to accelerate the purchasing process</i>
Lack of safety and quality standards	No official regulatory body to promulgate standards	Department established its own quality and safety standards including monitoring guidelines
Periodic need to suspend monitoring standards	Malfunctioning equipment	Developed local expertise for repairing and maintaining equipment <i>Adopt preventative maintenance policy</i> <i>Increase budget for spare monitors</i>
Cancellation of routine surgical lists	PACU unavailable when needed due to accommodation of ICU patients Lack of functioning equipment Shortage of anaesthesiologists	<i>Increase budget for nurses and expand ICU utilisation</i> <i>Establish step-down units</i> <i>Increase budget for preventative maintenance of equipment</i> <i>Accelerate hiring process</i>
Lack of anaesthesia research	Lack of personnel and research equipment Shortage of intramural funding	Pursue clinical research projects that require few resources <i>Obtain extramural funding from CCMRC</i>

ponement or cancellation of scheduled operative cases. Severe shortages of personnel are mitigated at times by non-departmental residents from the Accident and Emergency Training Programme of the UWI (curriculum includes a rotation in the Anaesthesia Department), who assist anaesthesia staff in routine and emergency cases.

Post Anaesthesia Care Units (PACU)

A shortage of PACU beds occasionally arises because of limitations of the Surgical Intensive Care Unit (SICU) and the absence of a step-down unit. The SICU was constructed to accommodate 15 patients (including three acute, burn-injured patients), but due to financial limitations (insufficient budget for nurses and functioning equipment), no more than six patients have ever received simultaneous care in the facility. Financial con-

straints have also prevented the development of a step-down unit, compelling both medical and surgical ICU physicians to retain patients until they can be managed on a general floor. As ICUs become overburdened, patients requiring intensive care are managed in the PACU. This results in a deficiency of PACU beds, which leads to the cancellation of elective operations. Thus, financial limitations create inefficiencies in health care delivery that may increase the overall cost of providing intensive care services.

Obstetric anaesthesia/analgesia services

Ninety-five percent of caesarean deliveries are performed under general anaesthesia. The high utilisation of general anaesthesia by parturients may relate to a lack of information about regional analgesia in antenatal educational courses in Barbados, as well as an

absence of obstetric analgesia services at the QEH. One attempt was made in the late 1970s to provide obstetric analgesia services using a Canadian anaesthetist provided by the HOPE (Health Opportunities for People Everywhere) Foundation. However, the Hospital was unable to increase anaesthesia staffing to accommodate the greater workload imposed by the new service. Another attempt to provide labour analgesia is anticipated in 1997, and will include increased anaesthesia staff, as well as efforts to educate parturients about the benefits and risks of regional *vs* general anaesthesia.

Anaesthetic drugs

Inhalation anaesthesia is usually conducted with halothane, enflurane, isoflurane or desflurane (sevoflurane is not available). Whenever feasible, low fresh gas flows (closed circuit) are employed to minimise the cost of the inhalational anaesthetic. Pancuronium and atracurium are the commonly used muscle relaxants. Fentanyl and sufentanil are used extensively. Propofol is the most frequently employed induction agent for day surgery patients. (Anaesthetists in Barbados gained experience with propofol during the initial multicentre drug trials in 1987). Hospital administrators have tolerated the Department's use of newer (more expensive) anaesthetic agents, as the use of these agents has not increased anaesthesia expenditure beyond the general inflation of the medical budget; anaesthesia drugs consume about 1% of the total Hospital budget.

Medical gas supply

The hospital utilises a pipeline system to supply operating rooms (ORs) and ICUs with oxygen, compressed air and nitrous oxide. Oxygen and compressed air are manufactured on the island, and are inexpensive. By contrast, nitrous oxide needs to be imported and is, therefore, expensive. In 1985, the Department of Anaesthesia began substituting air/oxygen for nitrous oxide/oxygen during general anaesthesia and noted a cost saving of US \$5 per anaesthetic without adverse clinical consequences.¹⁷ Thus, anaesthesia machines have been modified to deliver compressed air and, now, only negligible amounts of nitrous oxide are used.

The QEH purchased an oxygen concentrator (Rimer Alco - OC73) in 1986 to meet its oxygen demands and reduce oxygen expenditure. The concentrator can produce 19 M³.hr⁻¹ of oxygen at 92–95% purity (Rimer Alco - OC73 instruction manual) to help meet the oxygen requirements of the ORs and ICUs. The concentrator works by drawing atmospheric air into a compressor, and compresses it to 100

psig. The compressed air enters into a tower containing zeolite (dust free aluminium silicate), that adsorbs the majority of the nitrogen and water-vapour.¹⁸ As the zeolite becomes saturated, the air flow is transferred via a system of time-cycled valves to a second tower. This allows the nitrogen in the first tower to be evacuated by a vacuum pump and prepares the system for its next cycle. The gas that emerges from the concentrator has a high concentration of oxygen (95%) mixed with small proportions of nitrogen and rare gases (principally argon). A booster pump is used to increase the pressure of the concentrated oxygen to 145 psig for storage and distribution.

Unlike the field trial concentrators in Egypt, dust has not affected the air filters of the QEH concentrator.¹⁹ The primary problem with the Rimer Alco concentrator relate to the piston rings and valves of the compressor and the booster pump, which frequently become eroded. As a result, the oxygen concentrator has been out of service about 35% of the time since its installation. Most of this down-time has been related to the procurement of imported parts via the bureaucratic purchasing process. Nonetheless, it is still more cost-effective to supply oxygen from a concentrator (via pipelines) than from cylinders. Indeed, the oxygen expenditure has been reduced by about 50% since the QEH purchased the concentrator. Such cost savings favour the use of oxygen concentrators in developing countries,²⁰ and QEH is contemplating the purchase of a second, larger unit in near future.

Barbados lacks national safety and quality standards such as those provided by the National Fire Protection Association (NFPA) or the Compressed Gas Association (CGA) in North America.²¹ The absence of such standards (including required maintenance procedures) was responsible, in part, for a failure of the medical pipeline system at QEH in 1995. Because of the high ambient humidity in Barbados (mean 78%), water vapour accumulated in the air compressor. This eventually led to deposition of water in the air lines, as the humidified compressed air (100 psig) was decompressed to 55 psig in pipelines (Joule-Thompson effect). The problem went undetected until technologically-advanced Puritan Bennett 7200 ventilators replaced the mechanically simpler Bird Mark 8 and IMV (intermittent mandatory ventilation) ventilators. The water in the air line exceeded the capacity of the water traps of the new ventilators, causing the electronic valves and sensors to fail. This led to the cancellation of elective operative procedures for a two-week period. The problem of water in the compressed air supply was solved via installation of large self-draining water traps at the origin of the pipeline

system. To prevent future failures of the gas delivery system, the QEH has instituted an annual inspection and maintenance programme, which incorporates quality standards similar to those of developed countries.

Anaesthesia equipment

Boyle anaesthesia machines began arriving from England in the late 1930's, replacing the paraphernalia used to administer open drop ether. These machines, with some modifications, served the main ORs of Barbados until 1988, when they were replaced with more modern equipment (Ohmeda Excel 210 anaesthetic machines with Ohmeda 7000 ventilators). The Boyle machines still find use in anaesthesia sites remote from the main OR suite. Datex Cardiocap AS3 monitors are used for invasive as well as non-invasive monitoring (including spirometry).

Maintenance of anaesthetic equipment in Barbados is difficult. Defective equipment is often shipped to North America, or engineers come from overseas to make repairs. Dealerships do not consider it cost-effective to provide local expertise for repairs, given the small number of units on the island. Due to the complex technology of present-day monitors, it is often difficult for the Hospital's biomedical engineers to repair and service the units for other than minor problems. In addition, preventive maintenance of equipment has not been a priority of the QEH administration, which allocates only a small fraction of its budget for equipment repairs. Thus, an occasional crisis occurs, when an acute unanticipated shortage of functioning equipment threatens the delivery of safe anaesthesia care.

Technicians in Barbados are now encouraged to attend service sessions provided by overseas engineers. The technicians also maintain a log of common faults and have been more adept at handling equipment problems. Such developments have facilitated timely procurement of spare parts, and allow purchasers of new equipment to make decisions based on reliability data. Attendees at a recent Caribbean anaesthetists' conference (organised by the Barbados Society of Anaesthetists) suggested that the Caribbean nations standardise their anaesthesia equipment to reduce the cost of maintenance and repairs. Unfortunately, the wide disparity in needs and financial resources of each of the Caribbean nations may make this unfeasible.

Monitoring

Before 1987, routine monitoring consisted of palpation of peripheral pulse, auscultation via an oesophageal stethoscope, and measurement of blood pressure via sphygmomanometry; electrocardiograph monitoring was used only occasionally. In 1987, anaesthetists at

QEH began using modified sports watches as audible heart rate monitors during anaesthesia and during transport of patients to the PACU and/or ICU.²² Two types of sports watches were used, one with a finger probe (US \$40) to measure pulse rate (infrared plethysmography) and the other with a precordial belt containing a QRS sensor and transmitter (US \$120). These watches are readily available in sports equipment stores for pulse monitoring during exercise. They provide both visual (digital) and auditory information about pulse rate. The QEH anaesthetists altered these devices to amplify the auditory output (by transmitting beeper signals to a portable radio), and also replaced lithium batteries with less expensive penlight 1.5 volts batteries to enhance the battery life and decrease operational expenses. The modified watches were used until 1989, when pulse oximeters began appearing in operating rooms.

In the early 1990s, owing to foreign media broadcasts (especially television), Barbadians became aware of the value of monitoring standards and expected similar standards. Vacationers to the island also expected a quality of care commensurate with that in their native country. In addition, medico-legal liability became a concern. Thus, the Department of Anaesthesia purchased Datex Cardiocap monitors and established its own monitoring guidelines similar to those of the Canadian and American anaesthesia societies. Guidelines at the QEH, however, mandate the use of continuous capnography during all anaesthetics and for all SICU patients who require tracheal intubation. The Anaesthesia Department computed the cost of routine intraoperative monitoring (ECG, blood pressure, inspiratory concentration of oxygen and nitrous oxide, capnography, oxygraphy and oximetry), which, in 1993, did not exceed US \$5 per patient.

With the establishment of invasive cardiology services, transoesophageal echocardiography (TEE) monitoring was introduced in 1995 to monitor cardiac function during heart surgery. Transoesophageal echocardiography has also been useful to evaluate cardiac dysfunction or suspected myocardial ischaemia in SICU patients and in patients undergoing non-cardiac operations. Because of the high cost of pulmonary artery catheters (PAC), TEE is often preferred to PAC for monitoring cardiac patients for non-cardiac surgery.

Anaesthesia audit

Many anaesthesia supplies had been non-disposable (circuits, tracheal tubes) until 1985 when a fear of nosocomial infections prompted the transition to disposable items. Barbados was ill-prepared for a dependence on disposables, and sporadic shortages of anaesthetic supplies occurred. The necessity to pro-

cure supplies rapidly from overseas was hampered by both a bureaucratic purchasing process and restricted budgets: obtaining goods often took 6–12 mo. The need for careful planning was obvious, and led to the development of an anaesthesia audit in 1991. An audit form was completed for each anaesthetic administered and included data on anaesthetic drugs as well as disposable items to determine the rates at which products were consumed. Subsequently, periodic surveys have been used, allowing analysis and optimization of the cost-effectiveness of anaesthetic techniques, as well as preventing unanticipated shortages of supplies.

Day surgical cases

Only about 10% of the surgical case load at QEH involves day surgery or same day admission. Studies have indicated that the cost of providing medical services in developed countries can be reduced by 20–30% by performing surgery on an ambulatory or same day admission basis.^{23–27} In addition, outpatient surgery (47% of paediatric surgical cases) in Jamaica, a developing country, has been evaluated, and appears to be safe, effective, inexpensive and a desirable means of health care delivery.²⁶ Nonetheless, considerable impediments exist to establish an ambulatory surgery centre in a developing country. For example, QEH lacks preoperative screening facilities, has insufficient PACU space, and frequently experiences unanticipated shortages of staff and functioning equipment. Indeed, the establishment of a day surgery unit at QEH will require investments to solve these problems. The authors feel that such investment is worthwhile and will ultimately decrease the overall costs of health care delivery in Barbados.

Academic and research activities

The Commonwealth Caribbean Medical Research Council (CCMRC) and the University of West Indies have provided limited funding for clinical investigations, but no funds have been allocated to support anaesthesia research. The Hospital budget barely suffices for provision of anaesthesia and intensive care services: no money is allocated for research. Thus, the Department of Anaesthesia has pursued clinically-oriented projects, using existing facilities and equipment. Despite resource limitations and shortage of personnel, staff are encouraged to pursue academic interests. Recent academic works relate to the utility of capnometry in pregnancy,^{28,29} interpretations of capnograms,³⁰ and replacement of nitrous oxide by compressed air during general anaesthesia.¹⁷ The Department has also succeeded in creating a multimedia programme on capnography, and is currently exploring the possibility of using multimedia presentations as teaching tools.

The CCMRC organises regional conferences in Barbados that provide a forum for the presentation of medical research of local, regional, and international investigators.³¹ The Faculty of Medical Sciences (Barbados) has two continuing medical education conferences annually, which, from time to time, include anaesthesia topics. In addition, every two to three years, the Barbados Society of Anaesthesiologists organises a regional anaesthesia conference. Furthermore, anaesthesia societies and other scientific organisations in developed countries occasionally conduct their scientific meetings in Barbados, thus combining academic activity with vacation.³²

Anaesthesia education for the public

The Department of Anaesthesia has embarked upon a programme to increase public awareness about anaesthesia. It is anticipated that this educational programme will improve public relations, decrease perioperative anxiety among patients, and enhance the efficiency of preoperative visits. The initial approach to public education has included a brief video tape chronicling perioperative events from admission until the time of discharge from the Hospital. The video was produced by the Department in association with the government-owned Barbados Information Service and has been broadcast twice on the local television station. The Department has plans to produce additional videos, which will be aired at outpatient surgical clinics and preoperative holding areas.

Conclusion

In spite of its status as a small developing country, Barbados has been able to provide modern medical care at the Queen Elizabeth Hospital including some “state-of-the-art” technology. The inexorable pursuit of the latest technology and medical advances, however, has often been in discord with the infrastructural and financial limitations of this developing nation. Indeed, financial constraints in conjunction with the bureaucratic administration have caused the Anaesthesia Department at QEH to experience critical shortage of supplies, functioning equipment and personnel. The Department, however, has overcome many problems through implementation of pro-active policies, based, in part, upon departmental research and surveys. To ensure that scarce resources are allocated in accordance with the needs of the Department requires effective communication between the Department and hospital administration. The continuous delivery of high quality anaesthesia services mandates careful planning by administrators, judicious resource allocation, and the provision of adequate support services.

The authors hope that this report will stimulate an exchange of information among anaesthetists in developing countries, so better strategies can be developed to improve the quality and cost-effectiveness of anaesthesia services in the Third World. The Department welcomes residents and anaesthetists from developed countries to visit QEH, to exchange ideas and to learn about the challenges inherent to the practice of anaesthesia in a developing nation.

Acknowledgments

The authors wish to thank Ms. Robin Smith-Walker for her help in preparing and typing this manuscript.

References

- 1 Ministry of Health, Barbados 1995. Annual Report of the Chief Medical Officer for the Year 1993; 2.
- 2 Ministry of Health, Barbados 1995. Annual Report of the Chief Medical Officer for the Year 1993; 4.
- 3 Walters J, Fraser HS, Alleyne GAO. Use by visitors of the services of the Queen Elizabeth Hospital, Barbados, West Indian Medical Journal 1993; 42: 13-17.
- 4 Register of Baptism. Archives of Barbados 1875; RL2/61: 292.
- 5 In Memorium. H E G Boyle, OBE, FRCS. Harrisonian, Dec 1941; 26: 48.
- 6 Watt OM. The evolution of the Boyle apparatus, 1917-67. Anaesthesia 1968; 23: 103-17.
- 7 Anaesthesia, general and local. Seventeenth International Medical Congress, Proceedings of Sections. BMJ 1913; 2: 478.
- 8 Foregger R. Richard von Foregger, PhD., 1872-1960. Manufacturer of anesthesia equipment. Anesthesiology 1996; 84: 190-200.
- 9 Hadfield CF. Eminent anaesthetists: H. Edmund G. Boyle. Br J Anaesth 1950; 22: 107-17.
- 10 Hellinwell PJ. Editorial. Anaesthesia 1982; 37: 394-7.
- 11 Register of Baptisms. Archives of Barbados RL2/84 1887; 94: 81.
- 12 Collins VJ. History of anesthesiology. In: Collins VJ (Ed.). Principles of Anesthesiology, 2nd ed. Philadelphia: Lea & Febiger, 1980: 20.
- 13 Bourne W. Mysterious Waters to Guard. Essays and Addresses on Anaesthesia. Springfield, IL: Charles C. Thomas, 1955.
- 14 Canadian Anaesthetists Society Medal. Can Anaesth Soc J 1962; 9: 373-4.
- 15 Obituaries. Dr. Wesley Bourne. Canadian Med Ass J 1965; 92: 895-6.
- 16 Skinner BS. A new epidural cannula. Can Anaesth Soc J 1966; 13: 622-4.
- 17 Moseley H, Kumar AY, Bhavani Shankar K, Rao PS, Homi J. Should air/oxygen replace nitrous oxide-oxygen in general anaesthesia. Anaesthesia, 1987; 42: 609-12.
- 18 Carter JA, Baskett PJE, Simpson PJ. The "PermoX" oxygen concentrator. Its mode of action, performance, and potential application. Anaesthesia 1985; 40: 560-5.
- 19 Dobson M, Peel D, Khallaf N. Field trial of oxygen concentrators in upper Egypt. Lancet 1996; 347: 1597-9.
- 20 Dobson MB. Oxygen concentrators offer cost savings for developing countries. A study based on Papua New Guinea. Anaesthesia 1991; 46: 217-9.
- 21 Dorsch JA, Dorsch SE. Medical gas distribution systems. In: Dorsch JA, Dorsch SE (Eds.). Understanding Anesthesia Equipment. Construction, Care and Complications, 3rd ed. Baltimore: Williams & Wilkins, 1994: 26.
- 22 Shankar KB, Moseley HSL, Kumar AY, Jones PA. Portable monitoring devices (Letter). Anaesthesia 1990; 45: 257.
- 23 Detmer DE, Gelijns AC. Ambulatory surgery. A more cost-effective treatment strategy? Arch Surg 1994; 129: 123-7.
- 24 Musser DJ, Calligaro KD, Dougherty MJ, Raviola CA, DeLaurentis DA. Safety and cost-efficiency of 24-hour hospitalization for carotid endarterectomy. Ann Vasc Surg 1996; 10: 143-6.
- 25 Laffaye HA. The impact of an ambulatory surgical service in a community hospital. Arch Surg 1989; 124: 601-3.
- 26 EI-Shafie M, Shapiro RP. Outpatient pediatric surgery in a developing country. Pediatrics 1977; 60: 600-2.
- 27 Vaughan RW, Aluise JJ, McLaughlin CP. Ambulatory surgery and the hospital. Health Care Manage Rev 1991; 16: 15-25.
- 28 Shankar KB, Moseley H, Kumar Y, Vemula V. Arterial to end-tidal carbon dioxide tension difference during Caesarean section anaesthesia. Anaesthesia 1986; 41: 698-702.
- 29 Bhavani Shankar K, Moseley H, Vemula V, Kumar Y. Physiological dead space during general anaesthesia for Caesarean section. Can J Anaesth 1987; 34: 373-6.
- 30 Bhavani-Shankar K, Moseley H, Kumar AY, Delph Y. Capnometry and anaesthesia. Can J Anaesth 1992; 39: 617-32.
- 31 Proceedings of the 40th Scientific Meeting of Commonwealth Caribbean Medical Research Council. Barbados, 1995. West Indian Medical Journal 1995; 44: 14-57.
- 32 A symposium: ventricular remodelling and unloading following myocardial infarction. April, 1991, Barbados. Am J Cardiol 1991; 68:1D-131.