1

An Introduction to the World of Intensive Care Medicine

How a little girl helped to save the world

Intensive care doctor:
intensive, critical care doctor,
intensive care medicine doctor,
resuscitationist, but, ultimately,
just a human.

It was a beautiful sunny August evening in Copenhagen as Vivi danced in her garden after returning home from school. She was a happy twelve-year-old girl, with sandy-golden hair and apple-red cheeks. Life was tough since her parents had separated; her mum struggled to make ends meet working as a hatmaker. She watched her daughter through the window, dancing barefoot on the grass as she giggled and smiled to herself. Forty-eight hours later, Vivi was about to die. This is the story of the people, practices and technology which allowed her instead to live. Her journey was the first step along a sixty-five-year-long journey that now enables us to enjoy life in the face of devastating critical illness. This is the story of how intensive care can save your life.

Vivi didn't notice the moment earlier that day when a water droplet landed on her hand.* Nor did she know that a million copies of the deadly poliomyelitis virus were in that water droplet as she rubbed her eyes at night. As her mother's lullaby sent her to sleep, the virus started its work. It travelled from her hands to the cells in her mouth, before passing through the cell membranes. As the sun went down, the virus infected her tonsils, the lymph nodes in her neck and finally her intestines. By the morning Vivi had a headache which stopped her from dancing. Her mum's cool hand felt Vivi's hot head and rubbed her stiff neck. The next day Vivi struggled to fasten the buttons on her summer dress. Her fingers moved clumsily at the end of two heavy, weak arms. After being taken to the local Blegdam Hospital, she stopped responding to her name, as her breathing became rapid and shallow. Soon Vivi met the man who would save her life. He was the world's first intensive care doctor, Dr Bjorn Ibsen (Appendix: Figure 1).

Dr Ibsen was a 36-year-old anaesthetist when he met

* While transmission via water particles was most likely and typical for this infection, it is impossible to say with certainty that this is the exact path of transmission in Vivi's case.

Vivi. It was clear to him that she was suffering from acute severe polio (acute meaning the disease started and progressed rapidly; severe because Vivi's polio caused her profound weakness). Twenty-seven people had already died of the disease in just the first two weeks of the Copenhagen polio outbreak in 1952. Before its end, more than three hundred people would contract polio, a third with the severe respiratory failure that Vivi was developing, with 130 people dying as a result. Dr Ibsen knew that the so-called iron lung – the last machine that could save Vivi – was already in use. This machine was Vivi's only chance of surviving the illness that had caused her respiratory muscles to become too weak to turn the air around her into breath. The iron lung created an airtight seal between a patient's chest and the outside world, allowing a powerful air pump to make a vacuum that would suck out the chest wall and cause air to flow into the lungs through the windpipe.

Dr Ibsen felt helpless as he watched Vivi's breathing become even shallower. The build-up of dissolved carbon dioxide gas in her bloodstream, normally removed by breathing, pushed her blood pressure ever higher and depressed her consciousness so much that she could no longer stop her saliva from choking her. Dr Ibsen decided to do something radical that would change medicine for ever.

In an operating theatre, Dr Ibsen's job as an anaesthetist was to administer powerful drugs that would render a person unconscious and then to use other drugs to stop all muscle contractions, including those of the breathing muscles. Only under these circumstances could a surgeon safely perform complex operations that required still and controlled access to the inside of the human body. To keep a patient alive in the meantime, Dr Ibsen would need to breathe for his patients by inserting a plastic tube into the trachea, or windpipe. Although normally inserted through the mouth or nose, occasionally a tube would be inserted directly into the trachea through the front of the neck – a procedure known as a tracheostomy.

For Dr Ibsen, Vivi's condition mirrored that of the patients he cared for every day. The difference here was that the muscle weakness was caused by the polio virus acting directly on the motor nerves and spinal cord that normally supplied Vivi's muscles with instructions. However, the solution was the same, and at 11.15 a.m. on 27 August 1952 Dr Ibsen took Vivi to the operating theatre, organised an emergency tracheostomy, attached the pipe in her trachea to an inflatable bag that he then squeezed, forcing air into the lungs using positive pressure.

This is the opposite of how humans normally breathe. Take a deep breath in right now and feel the large muscle in your abdomen, your diaphragm, pushing down while simultaneously the muscles between your ribs contract, pulling them upwards and outwards. Together this creates a negative pressure in the layers between the elastic lungs and the inside of the ribcage. This pressure is transmitted to the lungs, pulling them outwards, dropping the pressure in the 500 million tiny air sacs inside, and thus drawing in air. This is the moment when air becomes breath. Instead, though, Dr Ibsen was squeezing a bag to push air into the lungs, much like what happens if you hang your head out of a fast-moving car's window and open your mouth.

After one breath, Vivi's chest went up and then down. The second breath was easier than the first, and by the tenth breath her heavy eyes opened and she saw through life's windows once again.

It is often the simple ideas in life that lead to the most profound change. This was one such moment. To sustain and not just save a life, Dr Ibsen needed to take the next important step – to create a safe place in which to keep Vivi and gather a team of people to care for her by squeezing the bag until her respiratory muscles had recovered. No one knew how long this might take. In fact it took a team of medical students working shifts of up to eight hours each, continuously squeezing the bag – not too hard, not too softly – for months in a small temporary hospital ward to keep Vivi alive (Appendix: Figure 2). This was the world's first intensive care unit, requiring over 1,500 volunteer medical students to squeeze Vivi's bag and then the bags of countless other patients day in, day out for six months during the Copenhagen polio epidemic. Finally, in January 1953, the bag was replaced with a dedicated mechanical ventilator that would breathe for Vivi.

Against the odds, and despite being unable to move from the neck downwards, Vivi survived. Seven long years after becoming ill, she left hospital and moved into a newly built apartment complex with her mother that allowed her to live attached to her breathing machine twenty-four hours a day. Vivi was an extremely happy, lively and brave young lady. She had a passion for reading, using a stick in her mouth to turn the pages of her favourite books (Appendix: Figure 3), and she would paint jewellery by using a paintbrush held between her teeth. She often travelled to family parties, always accompanied by heavy batteries strapped underneath her wheelchair to power her mechanical lungs, and her beloved Border collie, Bobby, would help her pass the time while looking over the skyline of Copenhagen from the twelfth-floor apartment block. In time Vivi formed a special bond with one of her male carers, and the pair fell in love and were soon engaged, finding respite from the reality of Vivi's situation by spending long summer days together at a family summer house along with her dog Bobby.

Despite Vivi's years of extensive rehabilitation and care, the ongoing burden of disability that often accompanies survival from critical illness prevented her from regaining her full independence. Yet Vivi did not let the challenges she faced cast a shadow over what she had been gifted. Her mum had her daughter back, Vivi had her life back, and Dr Ibsen never looked back. Nor would medicine.

~

Intensive care is not simply a place, a collection of people or a life-support machine. Like a modern-day church, it uses specially designed buildings, expensive equipment, particular methods, and people trained in the art and practices of a certain tradition to focus all of their attention on one thing. Rather than the immortal god, intensive care focuses on the very mortal patient, caring for the sickest patient in any hospital.

The physical location can be called the intensive care unit (ICU), the high-dependency unit or simply critical care. It should contain 10 per cent of the total number of beds in the hospital and be located close to the operating theatres and the emergency department. Each individual bed area has specialised equipment including a life-support or breathing machine, multiple medication pumps, dialysis machines and monitoring equipment. The most important item next to each bed, however, is none of these. It is a patient's own nurse.

All patients in intensive care are there because they have failure of one or more of their vital organs. This could be lung failure, requiring a breathing machine as in the case of Vivi, but also heart failure, kidney failure, gut failure, metabolic failure, blood failure or even brain failure. Anyone with this degree of illness, requiring organ support, is critically ill. We can classify the severity of a patient's illness throughout the hospital – and the subsequent care that they need – into five different levels from 0 to 4. Level 0 patients are those with a relatively mild illness that can be safely treated in a normal hospital ward with one nurse per seven to twenty patients. Level 1 patients are those at risk of deterioration, who require more regular observations of their vital signs. They will often be cared for in an acute ward setting, with more frequent nursing interventions. Level 2 is where high-dependency care is needed. These patients are people with only one organ failing and they will be nursed in a ratio of one nurse to two patients. This is often delivered in an area that is next to, or even includes, intensive care. Meanwhile, sicker patients require level 3 care, where a highly trained nurse will be at their bedside every hour of every day. This most often occurs when patients need a life-support machine to help them breathe or where more than one organ system is failing. Occasionally, a patient needs so much complex equipment that they require more than one nurse. These patients are termed level 4 and they are always treated in an ICU. Here critically ill patients require not only special medicines or machines, but also time: time to dedicate care to their problems, and equipment to allow time for their bodies to heal. Essential to all of this is the dedicated nursing time they are given.

The skills an intensive care doctor needs are broad. We perform surgery by inserting tubes into people's chests, necks and blood vessels. We must be expert communicators, often meeting families for the first time to tell them the worst news of their lives. We help perform and interpret medical scans of every body part, from X-rays of bones to CT scans of the brain. We adjust the physiology of the body with powerful drugs that we must know like the back of our hands. Our environment is covered in monitors, displaying hundreds of pieces of information, glowing with complex, multi-coloured waveforms. We combine all of these skills to work out what is wrong with someone as their body struggles to live. We then try to fix the problems we have found by co-ordinating a team of people who can help.

Sometimes the breadth of knowledge and skills needed make me feel like an imposter in my own hospital. The first time I felt like this was in 2003. I was a medical student presenting to a large, polished audience of esteemed military plastic surgeons during their annual meeting. After spending a summer training in the Nevada desert with American military doctors, I wanted to share my experiences of this simulated battlefield exercise. As I stood up, the projector bulb flashing to life, my voice froze. For what seemed like an eternity, I just looked out at the perfectly ironed audience, asking myself: 'What right do I have to be here?' In some ways I was right to doubt myself: I was barely qualified to talk on this topic to an audience overflowing with experience. Fortunately, something clicked as my first slide hung on the projector screen behind me and the next twenty minutes flew past, but in the officers' mess afterwards, when people told me how much they had enjoyed my talk, I did not believe them.

Fifteen years later, I am perfectly qualified to speak on many subjects, but when I present at a medical conference, these feelings sometimes return, as they do for many other doctors. It is no wonder that we intensive care doctors feel unsure of ourselves when expected to assimilate the 13,000 diagnoses, 6,000 drugs and 4,000 surgical procedures that we may need in order to treat almost any disease at any time. It feels like being a family doctor, expected to know the entirety of medicine, except applying it only to the sickest patients. Our skills of being able to ask the right questions and knowing where to find the answers trumps any rote-learnt medical knowledge. In the hospital, we often barge into other medical specialities at a moment's notice, treating conditions that we may not have encountered for years, before leaving as swiftly as we arrived. We are expert problem-solvers, thinking on our feet while trying to keep our brain based on evidence.

Many of the notable moments in my career have involved this type of problem-solving rather than the recall of bland medical facts. While working in an emergency department, I remember thirty-two muddied rugby players from the local under-10s team squeezing into a busy waiting room one Saturday afternoon. A practical joke played by one of the opposing players – adding menthol muscle rub to the after-match curry – had backfired. All thirty-two children were holding bottles of water, constantly washing out their burning, minty mouths. After checking the chemical content of the muscle rub, it transpired a hot tongue was the least of their worries. The cream contained aspirin as the active ingredient, the willow-bark extract originally used by ancient Egyptians as a remedy for aches and pains. Unfortunately, aspirin is also a toxic drug when used in excess quantities, especially by children. Now faced with a waiting room full of scared children and worried parents, the standard approach of testing blood levels in every individual was less than ideal due to the time it would take. A more creative medical problem-solving approach was needed, so I stood at the entrance of the waiting room, the air thick with the smell of dirty boots and mud, and loudly asked: 'WHICH ONE OF YOU ATE THE MOST CURRY?'

Thankfully, a slim, young boy put up his hand, remembering how his friends had laughed at him for finishing his meal so quickly before his taste buds had been awoken by the menthol. We took him to one side and tested his blood. I read the results with relief, seeing that the level of salicylate acid (the chemical name for aspirin) was well below the threshold needing treatment. We could safely assume, given the boy's big appetite and his low weight compared with his peers, that the remaining players could all return to the pitch. There could only be one person deserving of man of the match after his blood test had spared his teammates from the sharp end of a needle.

~

When posed a tricky question during my post-graduate examinations, I would often play for time by responding with my stock phrase: 'Well, let's divide this answer into three main parts . . .' The few extra seconds this response gave me would bump-start my brain into generating at least one out of the three answers I had promised. However, when answering the question 'How do patients get into the

ICU?', there genuinely are three possible answers: the front door, the side door or the theatre door.

The emergency department is colloquially known as the hospital's 'front door'. It is the main route of entry for patients arriving by road or air ambulance, for patients self-presenting in an emergency or even for patients rolled out from a speeding car as I once witnessed. Those whose measurements of their physiological signs – including heart rate, blood pressure and conscious state – lead to them being assessed as critically ill are taken directly to an area called 'resus' in the emergency department. Short for 'resuscitation', this zone has individual patient bays ideally set up to care for the sickest of patients in an efficient, timely manner. Each area in resus has emergency drugs on stand-by, equipment to put you onto a life-support machine close at hand, and a high ratio of staff all trained and ready to save your life. It is like a miniature ICU that needs to act fast but only for a short period of time. Some doctors specialise in treating patients at this stage of their journey and call themselves resuscitationists. Intensive care doctors will visit resus when critically ill patients are referred to them.

As an intensive care consultant, there are some instantly recognisable numbers that flash up on my battered mobile pager time after time. Just reading the digits 915 – the number for resus – gives my adrenal gland a call to action even when I am sitting safely in my local pub ten miles away from the hospital. Resus is often the most exciting and dangerous point to care for patients as they arrive from the tangled outside world, covered in dirt, blood and jeans and with little prior information to go on. If you panic, they panic and others panic – and panic has never saved a life. As I walk through the red doors, never knowing what will be ahead, I mentally rehearse my most feared scenarios, take a slow deep breath and form an external veneer of calm to temper the maelstrom inside. I try to make pools of order in a sea of disorder. Intensivists often help to stabilise patients during this early phase of their illness, assisting in making a diagnosis or short-term plans as well as deciding whether patients are suitable for admission to the ICU. Only when the seas are calm are patients then safe to move on to the next stage of their journey to our ICU if they remain critically ill.

Around one-third of my patients are admitted to intensive care directly from another hospital ward – via the 'side door'. They may have spent days, weeks or even months in hospital before becoming ill enough to need critical care. The challenge in caring for a ward patient is very different compared with the blank slate of a resus patient. Stepping onto an unfamiliar ward to see a referral, I have a secret technique to quickly find the critically ill patient. Scanning the area, a curtain will be drawn around one bed space, with the feet of multiple nurses and doctors just visible under the bottom edge of this cloth barrier. Some feet stand still, watching. Others frantically move around this way and then that way. As I approach, the familiar beep of hospital monitors will be heard. Peering around the curtain, the details I have been told by the referring team merge with the image before me to form my immediate gut instinct.

Ward patient referrals come with a wealth of information, multiple test results, X-rays, pages of notes and – most dangerously – the opinions of others. Most errors in clinical reasoning are not due to incompetence or poor knowledge but are intrinsic to the software of human thinking. When confronted with time pressures, large amounts of data, complexity and uncertainty, our brain takes several reasonable shortcuts. It uses heuristics to short-circuit the need for deep thinking and instead relies upon experience, the opinions of others and decisions that reassure us. When our ancient ancestors were faced with a herd of wildebeest on the hot savannah, these shortcuts saved their lives; when we are faced with a critically ill patient on the ward, these shortcuts may save far fewer.

Today, when I am told by a colleague that, for example, a patient on the trauma ward is short of breath three days after a car accident due to severe infection, my instinct is to believe this. I look at their blood results, subconsciously focusing on those that confirm the assumption I have already made. I remember the face of the last patient I admitted from that same ward who died due to severe infection and I become determined that this time things will be different. My ape brain is happy, but my critical thinking is not. I cannot allow these shortcuts to be the end of my process. I need insight and training to warn me about these shortcuts that my other self is making. I need to go back to the start, to think for myself, be logical, and ask: 'What if that *isn't* the problem?' If I do not do this, I will miss the fact that this latest patient does not have an infection at all and that, in fact, they are bleeding inside – profusely, non-stop. Antibiotics and a life-support machine certainly would not help. What this latest patient needs is a surgeon to stop their bleeding. Thankfully the development of critical care as a specialty comes with insights from cognitive science, addressing some defects inherent to the human condition.

I have made a lot of mistakes as a doctor. However, I am not a bad doctor. What I am is a normal human, working in an abnormal environment. Most mistakes made in medicine relate not to deficits in knowledge or skill. I used to worry about missing that rare diagnosis or making complex procedural errors at the worst time, but I have never done this. I now know that the mistakes I have made – and am likely to make in the future – will be simple, predictable errors, not complex ones. They are the types of blunder that you will make tomorrow while shopping, talking with friends or driving. The conclusions we leap to based on heuristics often are correct, but they can also be wrong. You will search in the same place three times while looking for your house keys, convinced you left them right there. You will visit the shops and forget the one item that you went there for in the first place. But life will carry on.

Sadly, when a patient is balanced on the edges of life, these simple errors can lead to disaster. These are tolerated in other industries such as accountancy, banking or software development. In medicine, they can result in pain, suffering or death. Yet the same humans are involved.

The recognition of medical error as human error has allowed a gradual transformation in healthcare systems. Today it should be possible for a doctor to make a potentially serious mistake and for the system to prevent this from harming a patient. I may try to inject a fatal amount of air through a tube into a vein instead of the stomach, but a special attachment will prevent me from being able to do so. Intensive care nurtures a robust system that should be able to fail gracefully not catastrophically. It should compensate, have resilience and redundancy, in anticipation of human error. However, it is in no way perfect and has a long way to go.

These improvements have been achieved through three strands of innovation. Atul Gawande's paradigm-shifting book, *The Checklist Manifesto*, introduced to medicine simple yet effective techniques you already use when shopping to remember those essential items. His introduction of the World Health Organization's 'Surgical Safety Checklist' has saved millions of lives by ensuring that simple critical steps, such as checking a patient's name and allergies, are carried out for each and every operation. We have now adapted his checklists for intensive care procedures such as tracheotomies and daily ward rounds.

The second strand has borrowed techniques used in industries such as aviation to allow improved team behaviour during a crisis. Crew resource management (CRM) empowers junior staff to question the decisions made by senior members of the team, flattening hierarchy and thereby improving safety. CRM can help teams come together in the fog of a disaster and work together effectively and safely. During emergencies in critical care, I now take a step backwards rather than forwards to get an overview of the situation, assign roles and act on good ideas provided by others.

The final transformative strand was built on the work of Nobel Prize-winning Daniel Kahneman in his life-affirming book, *Thinking, Fast and Slow*. Recognising that medical error is effectively a manifestation of ingrained human heuristics has allowed commonly described cognitive errors to be anticipated in healthcare. Every day, I see evidence of anchoring bias, where an incorrect diagnostic label is permanently attached to a patient after being applied earlier by another doctor. I am aware I often test patients for rare diagnoses in the days after I care for another patient with that very diagnosis. I know that I seek information to confirm my gut feelings, often disposing of inconvenient facts that would otherwise produce psychological conflict known as cognitive dissonance. Mentally preparing myself for these human bugs can stop them from becoming ends in themselves. Knowing about them makes me a better intensive care doctor.

The final route of entry to the ICU – via the 'theatre door' – is for selected post-surgery patients. This can be in a planned manner or as the result of complications arising from the operation or anaesthesia. Certain major operations will need a period of heightened observation or organ support when the surgery is finished. These operations include major cancer surgery to the oesophagus, removing parts of a diseased lung, and heart operations. Sometimes, though an operation may not be a major procedure, the background ill health of the patient will necessitate admission to intensive care in a planned manner. Predicting this is difficult. Some hospitals offer exercise testing to analyse a patient's ability to cope with an operation. These tests are time-consuming, costly and not all patients can manage them. The explosion of consumer wearable technology prompted me to question whether simply wearing a watch measuring physiological signs could act as a surrogate for these more invasive tests. Although our research is ongoing, perhaps in the next ten years, wearable technology will improve our risk-prediction models to better care for patients after major surgery.

The planned need for post-surgery ICU admissions leads to significant challenges. Aside from the regular surges that can be anticipated throughout the winter, the capacity of a critical care unit is difficult to predict on a daily basis. Therefore, if your operation requires an intensive care bed, your fate can be determined by the busyness of the hospital the night prior to your operation. When faced with a critically ill patient who needs that last intensive care bed following a car accident, what would you tell the patient needing that bed to have their cancer surgery the next morning? There are only a limited number of times that surgeons, intensivists and nurses can say sorry to a patient before it sounds hollow. All too often the outcome from this pressurised system, running at nearly 100 per cent capacity, is that operations are frequently postponed. Although capacity expansion is the most obvious solution, it comes with significant financial costs. Therefore, the drive for healthcare efficiency has led to other solutions being explored. Any capacity in the system is seen as slack by finance departments rather than as an essential part of patient safety. Without the ability to flex, the system is stiff and fragile with a tendency to snap.

One innovative solution involves having an area of intensive care with absolutely no beds. This seems like a strange way to solve the issue of not having an empty bed, but often the lack of an available intensive care bed is because patients who have improved in the ICU do not then have a standard ward bed to move on to. Instead, having only a physical space in intensive care allows a patient to be admitted to an elective surgical ward, have their operation and then come to critical care on that same physical ward bed they arrived in. After twenty-four hours of close observation, they can then return to the same physical space on the ward where they were first admitted, and the cycle can then continue. This simple yet effective strategy has allowed hundreds of operations to proceed in the last year where previously many may have been cancelled.

~

Sixty-five years after that long hot summer in Copenhagen, the ICU is a very different place. Nearly every emergency hospital in the Western world now has a dedicated area, specially designed to look after critically ill patients. We no longer need the shifts of medical students who were used as breathing machines to keep patients alive during the polio epidemic in Copenhagen in 1952. Today, intensive care stands at the cutting edge of medicine, both technologically and through our use of highly specialised staff, drugs and therapies. This all involves significant costs, with a single night spent in intensive care costing as much as £3,000. As well as these financial costs, the human resource challenges required to look after patients are huge. A typical critical care team consists of one-to-one nursing, healthcare assistants, a team of general and specialist doctors, a pharmacist, a physiotherapist, a dietician, an occupational therapist, a social worker, a psychologist and a host of support services. Despite concerns about the high cost of intensive care treatments, it has been shown that treating a patient in ICU is cheaper than many other therapies including drugs used in primary-care settings. For example, analysis suggests that the cost for each additional life saved in intensive care is around £40,000, compared with £220,000 for the treatment of high cholesterol using statins in well patients.

Treating the most critically ill patients in ICU can markedly reduce their chances of dying. The average mortality rate for these patients has been incrementally decreasing over time thanks to better systems, better training, better equipment and evidence-based therapies. There are now more than 30 million patients admitted to intensive care worldwide every year, of whom 24 million people will survive. We can therefore estimate that, since Vivi became its first patient, intensive care has resulted in around half a billion people surviving critical illness. Yet it is not just maintaining life that has been an aim for critical care. When I look into a mother's eyes and tell her that we will do all we can to save her son, I mean that we will strive to save the quality of life that her son had before he was unwell. Evidence shows that intensive care is able to significantly increase the chance of survival from critical illness and of leading a meaningful life, not just being alive.

~

In the twenty years after becoming the first intensive care patient in the world, Vivi had grown up, fallen in love, got engaged and read endless books. Life was filled with colour and laughter. Sadly, however, as Vivi turned thirty, she became seriously ill. Her lungs remained weak, her breathing shallow, and she returned to Blegdam Hospital – this time not with polio, but as a consequence of escaping death the first time. Her shallow breathing meant she had recurrent chest infections, but this one was different. She was admitted in September 1971 with pneumonia, and this time she would not go home. She died peacefully, aged just thirty-two. Intensive care had given her a second chance at life twenty years earlier but it could not save her now.

Indeed, sixty-seven years later, it still cannot save everyone and we still have a lot to learn. We need to find out how being in intensive care can affect patients years after they have recovered. We need to debate the ethical and moral questions surrounding who *should* be treated and not only who *can* be treated. We need to develop as a specialty so that, if Vivi were brought into my hospital that second time today, she would not die. We also need to show the public what is possible, what is right, and what is not.