CRITICAL CARE MEDICINE CAMILLA PILLAY

1. **Describe the prevalence of causal conditions requiring admission to an Intensive Care Unit (UK-based ICU) and discuss the impact of ICU treatment on overall mortality outcomes.**

Baseline data of contributing causes of admission to UK adult critical care and high dependency units has been recorded prospectively in earlier national audits. Because of the need to provide consistent and informed evaluations of clinical practice, prevalent primary reasons for unit admission have been rigorously validated alongside mortality and morbidity outcomes using the Intensive Care National Audit & Research Centre Case Mix Programme database (CMPD). [1] The most common causes necessitating patient access to critical care are defined from surgical admissions following aortic or iliac aneurysms or dissections (5.7% of total patient admissions). Pneumonia (where organism aetiology is indeterminate) and bacterial pneumonia form the second and third most frequently observed diagnoses prompting intensive care interventions and account for a total of 6.3% of recorded UK-based critical care admissions. Comparative data from smaller multi-centre analyses have identified similar outcomes in UK-based patient cohorts but the applicability of these results in practice may be limited by data acquirement from regional areas that are insufficiently representative of the patient population of interest. [2-4]

As intensive care services remain a scarce and costly resource, patient access is tightly limited to those in whom critical care interventions will produce a clinically significant benefit. Critical care should be considered and integrated within a scope of care that has already incorporated attempts to improve events prompting admission to the intensive care setting. Determining the benefits of intensive care management on UK mortality outcomes (irrespective of admitting cause) has proved difficult in view of the inadequacy of evidence available to corroborate this. This may be attributed to the limitations of ICU interventions where death is inevitable as a consequence of severe underlying disease or where implementing clinical input is of negligible benefit at the stage of admission.

Maximising the utility and efficacy of critical care resources to reduce mortality can be broadly targeted in two ways. Modifying treatment pre-admission to prevent physiological derangements and ensuring that appropriate step down approaches to high dependency services post discharge are put in place may reduce the number of preventable ICU deaths. This has previously been explored in earlier British-based studies where significantly greater mortality ratios were reported with increasing length of hospital stay pre-admission, in those patients with higher physiological warning scores. [5, 6] For the future, validation of additional risk factors contributing towards in-patient and post-discharge mortality is anticipated to reliably determine prognosis in the ICU setting and inform clinical judgement.

## 2. How does the delivery of critical care services in the UK differ in service compare to other nations in the Western World?

Considerable variations exist between healthcare systems internationally and their corresponding clinical outcomes. In keeping with the developments imparted by the expansion and capacity of modern medicine, a substantial proportion of the healthcare budget in developed nations is accommodated by secondary hospital care expenditure, with critical care services accounting for a significant proportion of these costs.

Critical care medicine facilities in the United Kingdom have been mainly evaluated against equivalent services alongside or against those in North America and selected European countries in view of the extensive contributions of evidence that these nations provide in the literature. UK-based critical care delivery is assigned Level 3 care, where advanced or basic respiratory support is provided in the presence of organ failure affecting at least two systems. [7] However, comparisons with equivalent healthcare systems internationally are unclear in view of absent or inconsistent criteria used to define critical care provision in other nations. [8] In an earlier retrospective evaluation of critical care delivery across Western Europe and North America, adult intensive care beds accounted for a small percentage of total acute hospital beds (1.2%, 3.5 ICU beds per 100 000 people) in the UK. [8] This is not significantly different to the ratio of ICU to acute hospital beds reported in other Western nations, excluding the United States, suggesting that a similar focus of hospital expenditure in these countries is still principally placed on the provision of acute (non-intensive) medical care. [9, 10]

Of concern has been the inverse correlation demonstrated between the availability of critical care beds and hospital mortality. Higher frequencies of sepsis and sepsis mortality rates have been discerned with a lesser availability of critical care beds in previous observations of UK patient populations, in contrast to data acquired from Western European counterparts. Similar findings have also been replicated in recent retrospective comparisons of medical ICU admission between US and UK-based patient cohorts. [11] Lower rates of hospital mortality, physiological impairment and short-term requirements for mechanical ventilation in US-based critical care have partly been accounted for by the seven-fold greater number of beds available per head in contrast to those of UK intensive care delivery. Whilst associations between mortality and bed accessibility have been established, accurate interpretation of international variations in care provision can only be considered in context of other factors affecting the care outcome in the populations studied. Adjusting for differences in hospital care practices (between admission and discharge), disease prevalence and patient population characteristics is required in future evaluations to enable a complete representation of the variations in care between each nation.

Comparisons of critical care services in the UK with provisions of care observed in other countries have revealed significant differences in care output and mortality as a function of ICU bed availability. For the present time, further work is anticipated to identify additional factors influencing the delivery of care in each country and to facilitate accurate analyses of international differences in service provision.

## 3. Respiratory failure in critical care – causative mechanisms

In health, respiration is facilitated by the synergistic actions of normal lung function and the respiratory muscle pump. Respiratory failure is a consequence of impairment to either one of these components, resulting in an inability to oxygenate or eliminate carbon dioxide from mixed venous blood at the alveolar-capillary unit. It is typically defined by arterial blood gas measurements of a partial pressure of arterial oxygen ($PaO_2$) < 8kPa and/or arterial carbon dioxide tension ($PaCO_2$) of > 6kPa. Respiratory failure is additionally categorised into type 1 hypoxaemic and type 2 hypercapnic subtypes, characterised by parameters of a $PaO_2$ < 8kPa and a $PaO_2$ < 8kPa and $PaCO_2$ > 6kPa respectively.

In the critically ill, respiratory failure is a common cause of organ dysfunction and in-hospital mortality. Attempts to define the prevalence of respiratory failure have been met with difficulty due to the wide variability of criteria used to define respiratory failure and the heterogeneity of patient populations studied. [12] UK-based admissions to intensive care units precipitated by respiratory failure occur secondarily to acute severe asthma (accounting for 1.7% of ICU admissions), chronic obstructive pulmonary disease (COPD) (2.9%) and community acquired pneumonia (5.9%) with critical care in-patient mortalities reported for these conditions of 7%, 23% and 34.9% respectively. [13-15] In view of these findings ICU practice is aided by an understanding of the mechanisms prompting hypoxaemia and hypercapnia in patients, moreover to using this knowledge to implement and support a multimodal approach of treatment in the prevention of additional organ insult and dysfunction.

Severe arterial hypoxaemia defines type 1 respiratory failure. This disorder represents a disease process intrinsic to the lung itself and may be considered in context of pathological mechanisms reducing the oxygen content of arterial blood. Hypoxaemic respiratory failure most commonly results from disparities in the ratio of ventilation to perfusion (**V/Q mismatch**) present in COPD, acute severe asthma, acute (cardiac) pulmonary oedema and pulmonary embolism. V/Q mismatching can consequent in a physiological shunt of mixed venous blood to the systemic circulation or occur alongside severe **right to left intra-cardiac shunting**, which may result from a primary disorder in congenital heart disease. **Impairments to gas exchange** with extensive parenchymal lung disease and reductions in $PaO_2$ following a **decline in $FiO_2$** with changes in altitude are additionally detrimental to oxygenation.
Hypercapnic (type 2) respiratory failure is primarily a disorder of respiratory muscle pump impairment. Hypercapnia may manifest as imbalances between factors of **neural respiratory drive**, **central and peripheral nervous transmission to the lungs**, **intrinsic respiratory muscle capacity** and an **increased respiratory muscle load**, impairing ventilation and $CO_2$ removal from mixed venous blood. [16] Some degree of hypoxaemia exists alongside the changes observed in this subtype of respiratory failure and arises from the reduced availability of oxygen available for gas exchange following increases in physiological dead space observed in causative conditions (peripheral neuropathy, emphysema).
Interpretation of any subtype of respiratory failure must also be corroborated by the acid-base balance. In the context of hypercapnic respiratory failure, this enables important pathological and therapeutic distinctions to be made in distinguishing acute and chronic hypercapnia, allowing appropriate definitive management strategies to be determined.

Intensive care management of respiratory failure exists to aid ventilation and to circumvent the effects of hypoxaemia and hypercapnia on organ function. In recent years non-invasive ventilation (NIV) has become the mainstay of critical care therapy for acute respiratory failure, where severe hypoxaemia and hypercapnia are refractory to increments in the $FiO_2$. Its use as a first-line intervention has been validated in a number of diseases predisposing to hypercapnia (e.g.: patients

with an acidotic exacerbation of COPD) through clinically significant reductions in mortality. [17] The benefits of NIV in the treatment of acute respiratory failure are observed to be greatest where this is implemented early in the course of illness. [18]
Invasive ventilatory support is reserved for patients admitted to level 3 intensive care facilities. The requirements for ventilation are made in the presence of significant physiological deterioration before respiratory arrest occurs. The principle of ventilation in this context is to overcome impairments to respiratory muscle pump function, enabling increases in minute volume to facilitate gas exchange and adequate removal of carbon dioxide. Prolongation of ventilation is required in 5-10% of patients with pre-existing lung impairment alongside additional chronic co-morbidities. [19] In this subset of patients, hospital survival outcomes are determined by the severity of admitting illness, the extent of multi-organ dysfunction in addition to pre-morbid status prior to in-patient admission. [20]

## 4. Personal and professional goals

(Objective evaluated and discussed with team members during the course of the placement)

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