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Critical care resources, disaster preparedness, and sepsis management: Survey results from the Asia Pacific region

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ABSTRACT

There is paucity of data on critical care resources, disaster preparedness, and sepsis management in countries within the Asia Pacific region. An online survey was conducted from 15 April to 17 July 2020. Snowball sampling through the Asia Pacific Sepsis Alliance and network contacts was used to recruit respondents. Countries were grouped according to the World Bank Country Income 2019 classification into lower-middle income (LMIC), upper-middle income (UMIC), and high-income (HIC). Survey questions addressed to hospital characteristics, critical care resources, disaster preparedness, and sepsis management. In total, 59 hospitals from 15 countries responded (33 LMICs, 8 UMICs, 18 HICs) with most responses from the Philippines (10; 16.9%). Median [Inter-quartile range (IQR)] hospital and Intensive Care Unit (ICU) bed capacity was 798 (500–1,001) and 37 (19–59), respectively. Median (IQR) doctor-to-patient and nurse-to-patient day ratios were 1:5 (1:3–1:8) and 1:2 (1:1–1:2), respectively. Availability of 24/7 physiotherapy services, 24/7 Medical resonance Imaging (MRI), point-of-care lactate, and "reserve" antibiotics was limited. Most ICUs had a disaster management plan (88%) and access to Personal Protective Equipment (96%). The most commonly adopted sepsis guideline was the Surviving Sepsis Campaign guidelines (77%). LMIC/UMIC ICUs had lower nurse-to-patient ratio and surge capacity along with limited access to 24/7 physiotherapy and MRI services, and interventions like Extra Corporeal Membrane Oxygenation, and Continuous Renal Replacement Therapy. Self-reported adoption and adherence to sepsis guidelines was higher in LMICs/UMICs than HICs. In the Asia Pacific region, critical care resources, disaster preparedness and management of sepsis vary considerably between countries across different income categories. In particular, low surge and isolation capacity in LMICs highlights the need for better health service planning and preparation.

Key Words: Asia Pacific, Critical care resources, Sepsis, Lower-middle income, Upper-middle income, High-income

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1. Introduction

The emergence of the SARS-CoV-2 virus in 2019 and the subsequent COVID-19 pandemic has caused millions of deaths globally and prolonged unprecedented demand on health services. The rapid health care and disaster response to the COVID-19 pandemic stands in stark contrast to progress made on the prevention and management of sepsis, a signature condition in the Intensive Care Unit (ICU),[1] to which one in five deaths globally can be attributed each year.[2] Sepsis is defined as life-threatening organ dysfunction caused by a dysregulated host response to infection.[3] Crucially, sepsis is the number one cause of death in hospitals and can affect anyone, with an even higher risk among the very young, chronically ill, the elderly and vulnerable populations in low resource settings.[4]

Critically ill sepsis patients, including those with viral sepsis secondary to COVID-19, suffer substantial morbidity and high rates of hospital readmission, increasing the demand for healthcare resources.[5] Access to necessary critical care resources is essential to optimise sepsis outcomes through the provision of evidenced-based critical care and for an effective disaster response, as highlighted during the COVID-19 global pandemic.[6] However, there is considerable variation in the availability of critical care resources primarily due to the different healthcare systems, largely determined by the wealth, of individual countries.[7]

In 2017, the World Health Organisation (WHO) recognised sepsis as a global threat, the significance of which was underscored by the World Health Assembly sepsis resolution (70.7).[8] The resolution requires member states implement national programs and measures to improve the prevention, diagnosis, and management of sepsis along with better antimicrobial stewardship practices and develop strategies for evidenced-based policies and research. The ongoing COVID-19 pandemic has further highlighted the importance of disaster preparedness with appropriate resourcing irrespective of a country's income category.[9–11] With close to half of the global sepsis cases present in the Asia pacific region,[2,12] there is a need to better understand availability of critical care resources and adoption of sepsis management guidelines across the region in order to improve outcomes in these patients.[13–15]

Currently, there is limited data about the resources, organisational structures, staffing, clinical standards, diagnostic capability, and therapeutic options available in the Asia Pacific region to treat critically ill patients, and in particular those with sepsis.[16] Thus, we conducted this survey to map critical care resource availability, disaster preparedness and better understand approaches to sepsis management to inform health services planning and management across the Asia Pacific region.

2. Methods

This study was conceptualised, designed, coordinated, and executed by the Asia Pacific Sepsis Alliance (APSA) which is a regional network of the Global Sepsis Alliance. The working group comprised critical care clinicians and researchers from the Asia Pacific region with representation from both HICs and LMICs.[17]

2.1 Survey design

The survey was adapted from a similar critical care resources survey designed by the Latin America Intensive Care Network,[18] and modified to suit the regional setting. Since the survey was conducted during the early phase of the COVID-19 pandemic, questions specific to COVID-19 were added in addition to disaster preparedness and surge capacity.

Survey development was based on an iterative consensus process, with a total of 38 questions being finally included across demographic, critical care resource, sepsis management, quality improvement and research, and disaster preparedness domains (see supplementary 1). The survey included questions asking for closed-ended "yes"/ "no" response and where required a quantitative answer or descriptive qualifier.

Pilot testing of the survey questionnaire was conducted within the working group (10% of sample) to ensure clarity, consistency, logical flow, and to minimise time needed for completion. A participant information sheet was provided with the survey outlining the aim of the survey, instructions for completion and information on consent. Ethics approval was obtained from The Chinese University of Hong Kong Survey and Behavioural Research Ethics (SBRE-19-565).

2.2 Survey administration

The survey was conducted between 15 April 2020 and 17 June 2020. Participants were frontline healthcare workers who were recruited by snowball sampling, first through the APSA network in each country and then through their contacts. At the time of the survey the APSA network included 19 countries from the Asia Pacific region ranging from HICs to LMICs.

Participants were invited by email to complete an online survey. Each respondent provided confirmation that they understood participation was voluntary and that survey completion implied consent for researchers to share and publish the data. The survey was administered using a commercial application Survey Monkey Inc. (San Mateo, California, USA; `www.surveymonkey.com`). All deidentified survey data was stored on a secure server hosted by The Chinese University of Hong Kong.

2.3 Data collection

Survey data was collected under the following domains: hospital and ICU type along with their capacity, ICU workforce, diagnostics and pathology capability, clinical intervention and physiological monitoring capability, therapeutics, ICU quality improvement and research activities, disaster plan and resources, and the adoption and adherence to sepsis management guidelines.

2.4 Data synthesis and analysis

The collected data was transcribed into a data synthesis sheet (see supplementary 1a) and was subsequently categorised as per the World Bank income classification of the participating countries. Descriptive statistics were used to present the results. Categorical data was reported as percentage of total number of responses for each question while continuous data was reported as median (Interquartile range; IQR). Data analysis was performed using Microsoft Excel (Microsoft Corporation 2018; `https://office.microsoft.com/excel`). To account for the incomplete data entries, the respective denominators were adjusted for each subsection within each category and for individual items within each subsection for each survey question to reflect the total number responses and produce relative proportions.

3. Results

3.1 Survey responses and demographics

Survey results are reported as per the EQUATOR recommended Checklist for Reporting Survey Studies.[19] Eighty-five survey responses were received in total, of which 26 were excluded due to repeated "false starts" by respondents likely due to needing to gather the information required to complete the survey. Subsequently, results from 59 hospitals across 15 countries were included in the analysis providing a 79% response rate. Survey results represented HICs, UMICs and LMICs across the Asia Pacific region (see Figure 1).

A majority of respondents were from LMICs with participation being highest from the Philippines (10; 16.9%) followed by India (9; 15.3%). Response rates per survey subsection ranged from 100% for hospital type, bed capacity and disaster preparedness to 71% for the use of sepsis management guidelines.

Mean completion time for survey was 8 minutes (range 7 to 9 minutes).

Hospital characteristics regarding the catchment population, service level, hospital size and annual activity, ICU level and available bed capacity is summarised in Table 1.

Figure 1. Survey responses per country income ranking

The majority of hospitals treated both adults and paediatric patients and were tertiary or university affiliated hospitals with a median (IQR) of 798 (500-1,001) hospital beds and 3,000 (1,500-6,039) annual admissions. The median (IQR) number of ICU beds was 37 (19-59) and 74.6% ICUs were level III facilities.[21]

3.2 Critical care resources

3.2.1 *Workforce*

Respondents reported on ICU dedicated nursing and medical median staff ratios per patient across both day and night shifts, and ventilated and non-ventilated patients, along with the presence of a qualified Intensivist each shift, and access to allied health support (see Table 2).

Overall, median (IQR) doctor-to-patient ratio was 1:5 (1:3–1:8) and 1:9.5 (1:6–1:14) during day and night, respectively. The median nurse-to-patient ratio was 1:2, irrespective of the time of the day or ventilation status of the patient. Although doctor-to-patient ratios were similar across income groups, nurse-to-patient ratios were higher in HIC than UMIC or LMIC ICUs. An Intensivist was available on each shift in 69% of the ICUs across all income groups. Most allied health support including physiotherapy, pharmacy, nutritionist, and social worker were available during "business hours" in around 75% of ICUs in all income groups. However, 24-hour access to a physiotherapist was very limited across all income groups, including HICs with only 31% of ICUs having round-the-clock access to physiotherapist.

Table 1. Demographic characteristics of the participating hospitals

Characteristics		All (N = 59) %	HIC (N = 18) %	UMIC (N = 8) %	LMIC (N = 33) %
Hospital population	Adult	15	17	12	15
	Mixed[1]	85	83	88	85
Hospital type (level)	University[2]	76	33	88	79
	Regional[3]	19	67	12	12
	District[4]	5	-	-	9
ICU level[5]	III	75	94	88	61
	II	20	6	12	30
	I	5	0	0	9
Hospital beds	Median (IQR)	798 (500-1,001)	1187 (799-1,654)	1,000 (701-1,040)	599 (469-867)
Hospital admissions Median	Median (IQR)	3,000 (1,500-6,039)	3,510 (1,725-4,905)	3,429 (2,881-5,481)	2,495 (1,007-6,056)
ICU beds	Median (IQR)	37 (19-59)	50 (22-81)	49 (16-80)	35 (17-40)
HDU[6] beds	Median (IQR)	25 (13-48)	22 (13-65)	35 (20-40)	20 (12-40)

1. Mixed adult and paediatric population
2. University affiliated or tertiary academic centre
3. Regional hospital receiving referrals from smaller hospitals and clinics from a defined area
4. District or community hospitals providing primary care to the local population
5. ICU level as per the World Federation of Societies of Intensive and Critical Care Medicine [20]
6. High dependency unit or intermediate care beds

Note. ICU: Intensive care unit; IQR: Inter quartile range; HIC: High income countries; LMIC: Lower-middle income countries; UMIC: Upper middle-income countries

Table 2. ICU staffing ratios and human resourcing

Staff to Patient Ratios		All Median (IQR)	HIC Median (IQR)	UMIC Median (IQR)	LMIC Median (IQR)
Doctor	Night	1:5 (1:3-1:8)	1:4 (1:2-1:9)	1:4 (1:3-1:7)	1:5 (1:4-1:8)
	Day	1:9.5 (1:6-1:14)	1:10 (1:7-1:17)	1:8 (1:7-1:13)	1:10 (1:5-1:14)
Nurse	Day (ventilated)	1:2 (1:1-1:2)	1:1 (1:1-1:2)	1:2 (1:1-1:2)	1:2 (1:1-1:3)
	Night (ventilated)	1:2 (1:1-1:3)	1:2 (1:1-1:2)	1:3 (1:2-1:4)	1:2 (1:1-1:3)
	Day (non-ventilated)	1:2 (1:8-1:3)	1:2 (1:1-1:2)	1:2 (1:1-1:4)	1:3 (1:2-1:3)
	Night (non-ventilated)	1:2 (1:2-1:3)	1:2 (1:2-1:2)	1:3 (1:1-1:5)	1:3 (1:2-1:4)
ICU with Senior & Allied Staff		**%[1]**	**%**	**%**	**%**
Intensivist		69	75	50	64
Physiotherapist	24 hrs/7 days	13	31	0	4
	Limited[2]	77	69	100	77
Pharmacist		77	81	67	77
Nutritionist		89	94	83	88
Social worker		65	75	50	62

1. n/N denominator adjusted per total responses for each question
2. Business hours (Monday-Friday 08:00 – 17:00 hrs)

Note. HIC: High income countries; LMIC: Lower-middle income countries; UMIC: Upper middle-income countries

3.2.2 *Medical imaging and diagnostic pathology*

Respondents reported on ICU access to medical imaging, diagnostic pathology facilities and specific pathology tests during both business hours (limited access) and 24 hours/7 days per week (see Table 3).

Table 3. ICU access to medical imaging and diagnostic pathology

Medical Imaging	Availability	All %[1]	HIC %	UMIC %	LMIC %
Portable CXR	24 hours/7 days	94	88	100	96
	Limited[2]	3	12	0	1
Ultrasound	24 hours/7 days	81	88	100	73
	Limited	19	12	0	27
CT	24 hours/7 days	83	81	100	81
	Limited	15	12	0	19
MRI	24 hours/7 days	55	50	60	58
	Limited	36	50	20	31
	Nil	9	0	20	12
Diagnostic Pathology					
24/7 Hospital clinical laboratory		92	94	100	92
Blood culture		96	94	100	96
Viral assays	PCR	75	100	60	62
	RT-PCR	69	75	88	61
RT-PCR result	Median minutes (IQR)	450 (285-1,950)	360 (180-460)	360 (180-1,680)	1,080 (375-2,835)
ICU POCT[3]	ABG	92	94	100	89
	Lactate	68	69	80	65
	Glucose	98	100	100	92
Procalcitonin		83	94	75	77
Haematology	Blood counts	98	94	100	100
	Coagulation studies	100	100	100	100
Screening	Malaria	78	75	100	77
	Tuberculosis	89	88	100	89
	Dengue	85	63	100	96
	Ebola	15	38	0	4
	Clostridium Difficile	70	94	75	58

1. n/N denominator adjusted per total responses for each question
2. Business hours (Monday-Friday 08:00 – 17:00 hrs)
3. Point of Care Testing in ICU

Note. ABG: Arterial blood gas; CXR: Chest X-ray; IQR: Inter quartile range; ICU: Intensive care unit; MRI: Magnetic resonance imaging; POCT: Point of care testing; PCR: Polymerase chain reaction; RT-PCR: Reverse transcriptase PCR; HIC: High income countries; LMIC: Lower middle-income countries; UMIC: Upper middle-income countries

Portable chest x-ray, ultrasound and CT scan were available 24/7 in nearly all the ICUs across all income groups. However, 12% of LMIC and 20% of UMIC ICUs had no access to Medical Resonance Imaging (MRI). More than 92% of hospitals across all income categories reported 24-hour laboratory availability for haematology (98%) and biochemistry (94%). Similarly there was high utilisation of Point-of-Care Testing (POCT) for arterial blood gases in the ICUs across all income groups (92%). However, POCT for Lactate was only available in 68% of ICUs limiting assessment of clinical deterioration, an important factor used to determine sepsis severity.

Substantially lower access to Reverse-Transcriptase Polymerase Chain Reaction (RT-PCR) viral assays in LMIC ICUs (61% vs 69% in all ICUs) and a slower turnaround time for test results (1,080 minutes vs. 450 minutes in all ICUs) have important ramifications for disaster management during the COVID pandemic in LMIC ICUs.

Access to infectious disease screening varied considerably by income status and pathogen type. While most of the disease burden is borne in LMICs, access to testing was highest in UMIC across disease types (75%-100%). Lower screening access in HICs likely reflects the lower disease burden driven testing.

3.2.3 *Clinical interventions and monitoring*

Clinical interventions and monitoring commonly undertaken in the ICU, such as oxygenation, organ support, surgical procedures and invasive monitoring, typically used to manage critically ill patients was compared across all income groups (see Table 4).

Table 4. Clinical interventions, procedures and physiological monitoring undertaken in the ICU

Clinical Interventions	**All %[1]**	**HIC %**	**UMIC %**	**LMIC %**
Oxygen therapy	96	94	100	96
High flow nasal oxygen	70	100	80	50
Non-invasive ventilation	98	100	100	96
Invasive mechanical ventilation	98	94	100	100
ECMO	62	88	60	46
Continuous Renal Replacement Therapy	70	100	80	50
Haemodialysis	96	88	100	100
Plasmapheresis	77	88	60	73
Percutaneous Tracheostomy	83	87	60	85
Fibreoptic Bronchoscopy	85	94	80	81
Physiological Monitoring				
Electrocardiogram	96	94	100	96
Intra-arterial Pressure	92	100	80	85
Central Venous Pressure	89	88	80	81
Echocardiography	96	100	100	92
Pulse Oximetry	100	94	100	100
End Tidal CO_2	78	94	100	65
Cardiac Output	54	87	40	39
Intra-abdominal Pressure	56	75	40	44
Electroencephalogram	67	75	60	62
Intra-cranial Pressure	51	94	40	27

1. n/N denominator adjusted per total responses for each question

Note. CO_2: Carbon dioxide; ECMO: Extra corporeal membrane oxygenation; ICU: Intensive care unit; HIC: High income countries; LMIC: Lower middle-income countries; UMIC: Upper middle-income countries

A majority of clinical interventions undertaken were consistent in ICUs across all income groups. However, when comparing LMIC ICU's to HIC ICUs, only approximately 50% of LMIC ICUs could provide high flow nasal oxygen (50% vs. 100% HIC ICUs), Continuous Renal Replacement Therapy (50% vs. 100% HIC ICUs), and Extracorporeal Membrane Oxygenation (46% vs. 88% HIC ICUs).

Similarly, on comparison with HIC ICUs only approximately 50% of both UMIC and LMIC ICUs could provide complex physiological monitoring modalities. These included cardiac output measurement (UMIC 40% & LMIC 39% vs. 87% in HIC ICUs), intra-abdominal pressure monitoring (UMIC 40% & LMIC 44% vs. 75% in HIC ICUs), and intracranial pressure monitoring (UMIC 40% & LMIC 27% vs. 94% in HIC ICUs).

3.2.4 *Access to medications*

Intravenous fluids and medications including crystalloids, albumin, vasoactive drugs and Hydrocortisone were readily available to ICUs (96%-100%) across all income categories. Lower availability was noted of "other" colloid fluids in HIC ICUs (88%) and LMIC ICU's (85%) and may be explained by a shift away from the use of colloids in fluid resuscitation.[22]

Respondents reported on ICU access to antivirals, antibiotics and antifungals and other antibiotics (see Figure 2). The overall availability of antivirals and antifungals was limited in most ICUs in all income groups, in particular Remdesevir (12%), Ribarvirin (47%), Lopinavir (68%) and Echinocandins (67%).

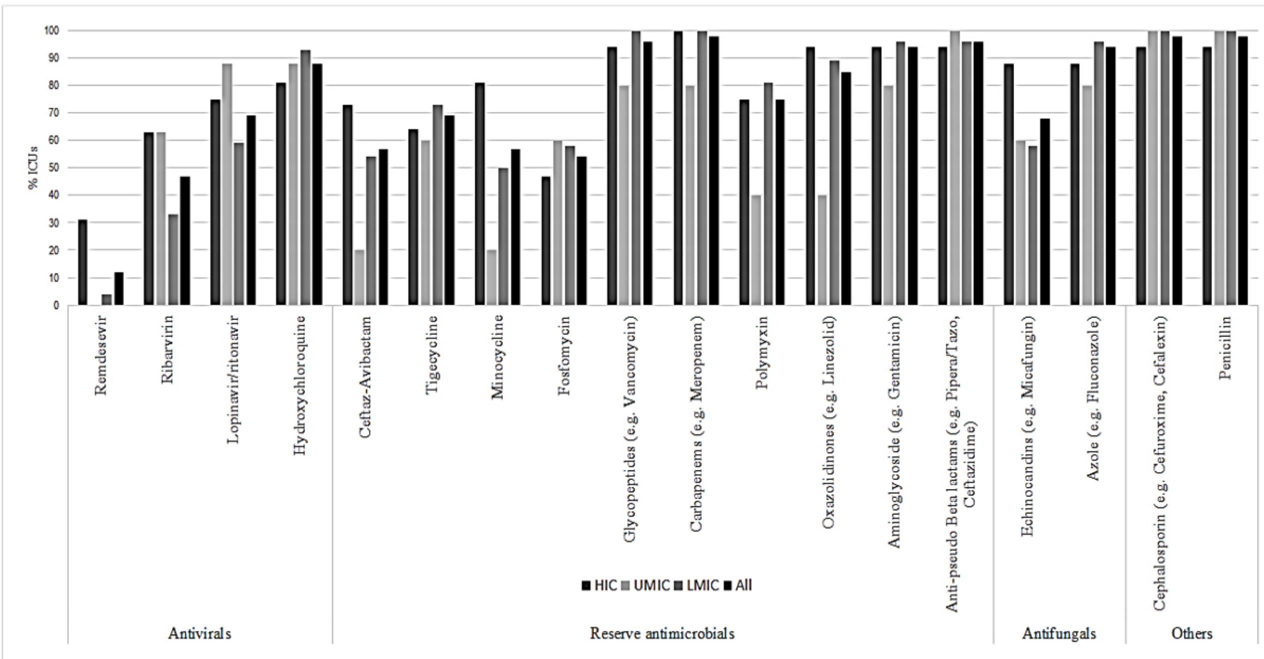

Figure 2. ICU access to antimicrobials

The antimicrobials investigated are listed in the World Health Organisation (WHO) access, watch, reserve (AWaRE) classification of antibiotics for evaluation and monitoring of use,[23] providing a tool for monitoring antibiotic consumption, defining targets and monitoring the effects of stewardship policies that aim to optimise antibiotic use and curb antimicrobial resistance. Antimicrobials classified as "watch antibiotics" were available in most ICUs across income groups except Minocycline and Fosfomycin which were available in only 50% of ICUs.

The availability of antibiotics classified as "reserve" antibiotics by the AWaRE program,[23] including Ceftazidime-Avibactam, Tigecycline, Polymyxin and Linezolid was limited to 57%-85% of ICUs. Distribution across the income levels varied with UMICs in general having less availability of antibiotics than LMIC and HIC ICUs.

3.2.5 *Disaster preparedness*

Overall, nearly all ICUs had a disaster plan (98%), including a COVID-19-specific policy, but fewer ICUs across all income groups had access to surge triage guidelines (71%) and only 75% had access to simulation training for disaster preparedness (see Table 5).

Overall, 90% or more ICUs had access to disaster management resources such as Personal Protective Equipment (PPE) including eye/face shields, N95 masks, gloves, and gowns. However, powered air purifying respirators were available in only 35% ICUs in all income groups with high availability HIC ICU's (100%) compared to only 25% of LMIC ICUs.

Limited access to the COVID-19 diagnostic test (RT-PCR) and slow result reporting time, particularly in LMIC ICUs which took three times longer than in HIC ICUs (see Table 3), negatively impacts on screening and isolation disaster plan policies for COVID-19 impeding effective pandemic disaster response and management. While the availability of COVID-19-specific medications was also limited with access to Remdesevir reported by only 12% of ICUs over all, and primarily in HIC ICUs. In contrast, 88% of all ICUs had access to Hydroxychloroquine with the highest availability reported by LMIC ICUs.

Table 5. Disaster preparedness and resources

Disaster Planning		All %[1]	HIC %	UMIC %	LMIC %
PPE use guideline		95	89	100	97
Screen & isolation policy for COVID-19		93	83	100	97
Surge bed capacity management		97	89	100	100
Surge triage guidelines		71	67	63	76
Workforce and staffing		97	94	100	97
Training/Simulation		75	67	88	76
Disaster Resources					
Personal Protective Equipment	Eye/face shields	95	89	100	97
	N95 masks	95	100	100	89
	Gowns	96	94	100	96
	Gloves	98	100	100	96
Alcohol hand hygiene		100	100	100	100
Powered, air purifying respirators		35	100	57	25
Isolation and Surge Capacity		**Median**	**Median**	**Median**	**Median**
Single room	Hospital	9	13	12	7
	ICU	7	11	10	6
Negative pressure room	Hospital	7	12	5	4
	ICU	4	7	4	2
Surge ICU beds		10	17	10	10
Peak ICU bed capacity		49	36	70	49
Peak ventilator capacity		49	32	40	50

1. n/N denominator adjusted per total responses for each question

Note. ICU: Intensive care unit; HIC: High income countries; LMIC: Lower middle-income countries; UMIC: Upper middle-income countries

Isolation and surge capacity are important determinants of effective pandemic disaster response. However, across the region there was a median of seven single isolation rooms and four negative pressure rooms accessible by the ICU. Overall, ICUs had a median surge capacity of 10 beds, though HIC ICUs reported a bed surge median capacity of 17 beds. While all ICUs reported a median peak capacity of 49 beds and ventilators, UMIC ICUs had the ability to peak to a median of 70 beds and 40 ventilators, and LMIC ICUs 49 and 50 respectively, equal or high than HIC ICUs. This could be attributed to higher patient to staffing ratio and a lower level of acuity in UMIC and LMIC ICUs than HIC ICUs.

3.3 Sepsis management and quality improvement

Sepsis clinical management guidelines were adopted broadly across the region in 86% of all ICUs. Adoption of any sepsis guideline, including Surviving Sepsis Campaign (SCC) COVID-19 guidelines[24] was lower in HIC ICUs (67%) than UMIC ICUs (100%) and LMIC ICUs (92%). This was conversely reflected in a higher adoption of nationally developed and unit based guidelines in HIC ICU's. The SSC guideline[25] was most commonly adopted in 76% of ICUs across all income groups (see Figure 3).

The availability of evidence based sepsis management guidelines is a key determinant of improving the quality of sepsis clinical care and outcomes. Self-reported adherence to guidelines in the clinical setting provides an important insight into utilisation in routine practice which ultimately has a critical impact on the delivery and effectiveness of clinical care. Overall, 93% of ICUs reported they "always" or "usually" adhered to the available sepsis guidelines. Self-reported adherence was highest in LMIC ICUs (100%) and lowest in HIC ICUs (80%).

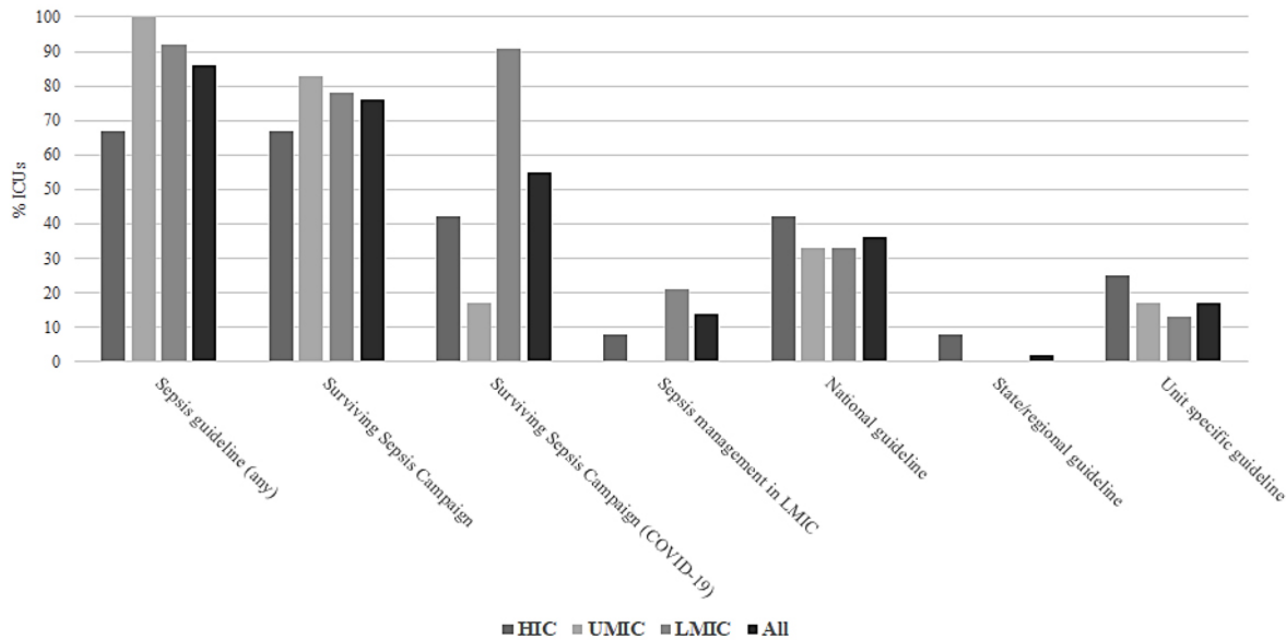

Figure 3. Evidence based sepsis management guidelines available in ICU

Quality improvement initiatives and research activities being undertaken in the ICUs was evaluated by exploring the degree to which targeted infection and antibiotic policies, programs and processes were implemented, and the scope and type of research being undertaken within the ICU (see Figure 4).

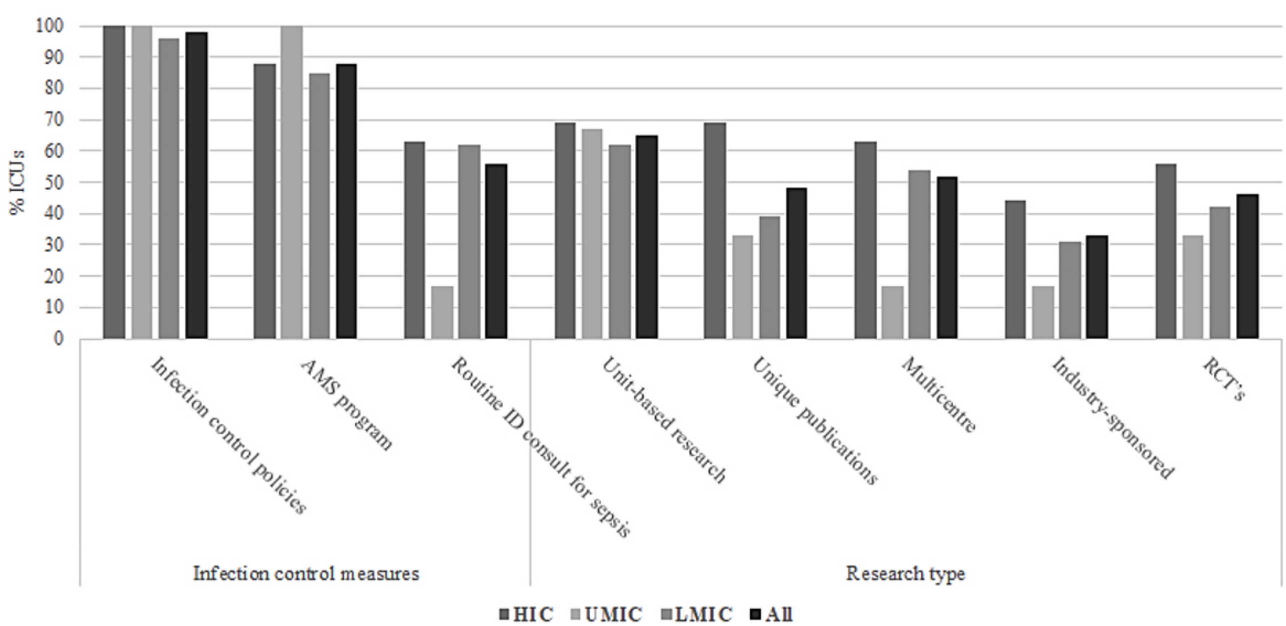

Figure 4. Self-reported adherence to sepsis management guidelines available in ICU

Infection control policies (98%) and antimicrobial stewardship programs (88%) were available in most ICUs and were comparable across all income groups. However, routine consultation with an infectious disease specialist for sepsis patients was varied and only available in 56% ICUs overall, with the lowest routine consultation occurring in UMICs (17%).

Research, in some form, was being undertaken in approximately 65% of ICUs across all income categories with HIC ICUs having the highest activity across all research types (see Figure 4). Unit-based research was most common followed by multicentre study's being undertaken, in 65% and 52% of ICUs respectively, with RCTs the study type in approximately 48% of ICUs across all income groups.

4. Discussion

In our survey most ICUs had access to critical care resources except 24/7 physiotherapy and MRI, point-of-care lactate, "reserve" antibiotics; and followed a guideline for sepsis management but were not well equipped to deal with a pandemic. There were key differences amongst the income categories, wherein UMICs/LMICs had lower availability of nursing staff, 24/7 physiotherapist, MRI, ECMO, CRRT, and limited isolation and surge capacity, but reported higher adoption and adherence to sepsis guidelines compared to HICs. Availability of antimicrobial agents varied based on local pathogen profile and expectedly availability of "watch" antibiotics was more consistent than "reserve" antibiotics. COVID-19-specific diagnostic testing and antivirals like Remedesevir were restricted predominantly to HICs.

When compared to previous studies, the ICU bed capacity in LMIC cohort of our survey was two to four times higher than other studies conducted in Asian,[26] Brazilian,[27] and African[28] ICUs. In terms of staffing, a higher nurse-to-patient ratio was noted in LMIC cohort of our survey than a previous study conducted in Brazil.[27] A previous review by Shultz et. al.,[16] reported lower nurse-to-patient ratio, limited access to physiotherapist, and limited research engagement in lower income countries which is consistent with our survey findings. Resource-limited settings are generally not conducive to high quality research.[29] This was also evident in our survey too as corresponding cohort was less engaged in clinical research and publishing the same.

Our survey has several strengths. Our survey had a good response rate (76%) which was higher than a previously conducted similar survey in the Latin America (53%).[18] We had participation from whole spectrum of World Bank income classification for countries ranging from HICs to LMICs which allowed studying disparities across various income categories with respect to critical care resources, sepsis management, and disaster preparedness. There are some limitations in our study. This survey was done in a small number of hospitals so findings may not be representative. Although all efforts were made to ensure survey sample to be representative of the studied region, snowballing technique used to disseminate the survey meant that survey respondents were largely limited to the contacts of the APSA members. This might limit the generalisability of the survey findings. Moreover, self-reported surveys like this have an inherent limitation as individual responses cannot be verified. Lastly, this survey might not provide true representation of the surge capacity during the COVID-19 pandemic in the region as it was conducted at the start of the pandemic. Since then, resource allocation and surge capacity may have changed as it's likely that the surge capacity in many ICUs was exceeded beyond their predicted capacity during subsequent COVID-19 peaks.

However, this survey provides insights on the various aspects of critical care resources and sepsis management, and the disparities in the availability of critical care resources between countries in the Asia Pacific region as per their income group, particularly while preparing for a disaster like COVID-19 pandemic. Future research is needed in a more representative cohort of ICUs across the Asia Pacific region in order to assess the gradient in critical care resourcing, surge capacity and capability, and the evolution of critical care services in response to the COVID-19 pandemic, particularly in lower income countries.

5. Conclusions

There is a paucity of data about critical care resources, organisational structures, staffing, clinical standards, diagnostic and therapeutic capability, disaster preparedness, sepsis management and the variation across high and low resource countries in the Asia Pacific region. Overall, critical care resourcing was relatively similar in ICUs from all income settings, largely attributable to the ICU organisational model that requires 24/7 operational readiness and appropriate resourcing to safely manage critically ill patients and support acute care hospitals. However, higher patient to staff ratios and limited access to allied support, medical imaging and diagnostic pathology in LMIC ICUs may impede the operational readiness, flexibility and timeliness needed to effectively respond to fluctuations in demand for intensive care. Compounding these constraints in disaster response scenarios, such as the COVID-19 pandemic, would be limited isolation and surge capacity in LMIC ICU's which could undermine disaster responsiveness. The association between COVID-19 and viral sepsis in critically ill patients warrants improving access to evidence based sepsis management guidelines and the resources required to ensure uniformly high adherence in ICUs to across all resource settings. This survey identifies priorities for health policy, management and clinicians to improve critical care resourcing, disaster preparedness, and sepsis outcomes. Further research is warranted to better understand how ICU resourcing and processes changed over the duration of the COVID-19 pandemic, particularly in LMIC and UMICs, to inform health service planning and preparedness in the Asia Pacific region into the future.

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CONFLICTS OF INTEREST DISCLOSURE

The authors declare they have no conflicts of interest.

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