INTRODUCTION

The COVID-19 pandemic is a maelstrom that caught much of the world by surprise, in both its speed of spread, relatively high mortality, and global affliction [1]. Singapore, as the transport nexus in Asia, with extensive air and sea connectivity to the rest of the world, is at heightened exposure risk to the pandemic. Expectedly, the first positive COVID-19 case in Singapore was an imported one from Hubei province, China, and reported on 23 Jan 2020 [2]. As control measures ramped up progressively across the country, to limit transmission and reduce exposure risks of frontline workers, healthcare institutional practices are also forced to adapt dramatically in a short span of time [3]. Fortuitously, Singapore had drawn valuable lessons from the 2003 Severe Acute Respiratory Syndrome (SARS) outbreak, and drawer plans and logistical stockpiles were largely in place for rapid deployment to deal with the unravelling situation.

The conduct of echocardiographic studies, be it transthoracic echocardiograms (TTEs), stress echocardiograms, and transoesophageal echocardiograms (TEEs), is considered not a low risk procedure due to its inherently prolonged close contact with patients. Sonographers performing TTEs need to be in close proximity to the patients for at least 20–30 minutes for a comprehensive study, while patients undergoing oesophageal intubations for TEEs may gag and cough during the procedures [4-7], and patients running on treadmills for the stress echocardiograms may potentially aerosolize their forcefully expired breaths during strenuous phases of the test [8]. These procedures will inadvertently subject the staff at increased risk of virus exposure, and hence the recommendation for personal protective equipment (PPE), ranging from droplet to airborne precautions, for performing TTE and TEE procedures, respectively.

STRATEGIES UNDERTAKEN BY NATIONAL HEART CENTRE SINGAPORE ECHO LABORATORY

Multiple governmental bodies and cardiac societies had published, in rapid succession, various guidelines and recommendations during this period of heightened infectious disease risk [9-13]. The Singapore government had been lauded for taking decisive and appropriate population level actions to contain the pandemic [14-16]. This included early and rapid contact tracing of confirmed cases, transparent and timely information dissemination to the public to raise awareness and knowledge of the disease, and more crucially, issuing isolation or quarantine orders to high risk contacts or suspected cases to facilitate early containment. These societal level measures constitute the “first line of defence” for the National Heart Centre Singapore (NHCS) echo laboratory, by systematically screening out high risk cases, either of their own volition (postponing their echocardiographic procedures)
studies if feeling unwell), by educating the public on the sense of strict hygiene standards to be maintained, or simply by keeping them home with isolation orders.

Nevertheless, the explosion in numbers of publications made it challenging to navigate the myriad documents to crystallize the recommendations, given the spectrum of operational and clinical differences across countries. Nevertheless, NHCS took the swathe of available data, and customized our own protocols to fit operational requirements.

In NHCS, existing infectious control protocols were reviewed and enhanced, with progressive implementation since late January 2020. Of the 62 echo laboratory staff (44 sonographers, 18 echocardiologists) who have performed or assisted in a total of 5571 echocardiographic studies in our labs from 1 February 2020 till 31 March 2020, none were found to be infected, or developed symptoms suspicious for the disease. To date, the updated clin-

| Table 1. Matrix of key principles of infection control in NHCS echo lab |
|-----------------|---|-----------------|
| **Principle** | **Category** | **Elaboration** |
| Management of echo examinations | UM | Avoid inappropriate or rarely appropriate procedures, and postponement or re-prioritization of non-urgent procedures. |
| | UM | Postponement for patients who are suspected cases, contacts of suspected cases, or who have been served varying levels of self-isolation/quarantine notices by government agencies. |
| | UM | Denial of same day echocardiographic examinations for patients who display or report active respiratory symptoms or fever, or who returned from overseas destinations within the last 14 days and not been observing the issued self-isolation/quarantine notices. |
| | UM, MM | Proceed with clinically indicated or urgent echocardiographic examinations (after review of requests by performing staff/physicians) with adoption of strict hygiene and personal protective standards protective equipment, garments and disinfection, especially for confirmed and suspected cases. |
| | MM | Focused echocardiographic examinations with shorter scan time to answer clinical questions for confirmed and suspected cases. |
| Management of echo laboratory staff | IM | Grouping of laboratory staff by their roles to form small functional teams to work in different locations or staggering their work and break hours to reduce physical contacts between teams. |
| | IM | Adhering to safe distancing rules during communal activities such as meals, daily short huddle meetings, and adopting of teleconferencing for educational and regular communication sessions. |
| | IM | Refreshing and up-skilling of personal protective equipping procedures and protocols, with strict adherence of recommended protocols at designated locations, for example donning of appropriate PPE for various procedures depending on risk of aerosols generation [17]. |
| | IM | Segregation of functional teams by physical locations such as inpatient viz-a-viz outpatient. |
| | IM | Mandatory for staff to take medical leave if unwell, and routine twice daily temperature checks and submission for all staff on duty. |
| | IM | Non-patient fronting administrative staff to: - Cross cover each other's functions whenever possible. - Stagger work hours, or - Work from home [16]. |
| Management of echo lab equipment, furnishings and office space | MM, IM | Increase frequency of disinfection and cleansing [18,19]. |
| | MM, IM | Utilization of disposable covers for examination couches. |
| | MM, IM | Thorough cleaning of the room and surrounding after each heightened risk patient. |
| | MM, IM | Dedicated portable ultrasound unit for use in isolation/COVID-19 wards. |
| Management of patients | UM | Temperature and history (travel, contact and clinical) screening before entering the lab at the NHCS lobby. |
| | MM | Patients deemed to have additional risk factor but asymptomatic will be cohorted and their scans performed in a designated area by staff in appropriate PPE. |
| | MM | Minimizing dwell and wait time in echo laboratory. |
| | MM | Physical segregation of patients and restricting number of accompanying caregivers in waiting areas and service counters. |

UM: upstream measures, MM: midstream measures, IM: in-stream measures, NHCS: National Heart Centre Singapore, PPE: personal protective equipment
ical workflows and processes appear to be effective in preventing transmission risks in the NHCS echo laboratory thus far, and we would like to share our experience and measures during this period.

The preventive measures implemented by the NHCS echo laboratory were classified as “upstream,” “midstream” or “in-stream.” The key principles in the design of the NHCS echo laboratory strategies and measures are summarized in Table 1 (detailed description of the measures is captured in the Supplementary Table 1, online-only Data Supplement).

- Upstream measures (UM): processes prior to arrival of the patient at the echo laboratory, to prevent high risk contacts or symptomatic patients from entering the laboratory in the first place.
- Midstream measures (MM): conduct risk mitigated or minimized echocardiographic examinations in the laboratory or by the bedside, to protect both patients and echo lab personnel during the extended contact time in the laboratory.
- In-stream measures (IM): all other background activities to strengthen baseline infection control measures, and cohorting of echo laboratory staff to minimize transmission risks or cross contaminations.

OUTCOMES

Following implementation of the above strategies and practices from end January 2020, the NHCS echo lab observed zero COVID-19 transmissions or contacts (accurate as of 18 April 2020). As anticipated, with more stringent re-prioritization and screening measures in place, the number of echocardiographic examinations performed in our centre has significantly reduced in February–March 2020 (a 26% drop in volume), when compared to the same period in 2019 (from 7159 to 5271 studies).

Of the total 5271 studies performed from 1 February to 31 March 2020, 1753 examinations (33%) were performed in the inpatient setting. Of these, the majority (n=1721, 98%) were TTEs, while the remaining were TEEs (n=32). Of note, 42 of these TTE studies were performed for patients with respiratory symptoms who were cohorted in acute respiratory wards at the Singapore General Hospital. Although these patients did not meet the Ministry of Health definitions [20-22] of either confirmed or suspected COVID-19, appropriate PPE (minimally surgical mask and gloves) are still required while attending to or performing echocardiographic examinations for them, as per hospital protocol. See Fig. 1 for the total number of echocardiographic studies done in February–March 2020, and Fig. 2 for
the echocardiographic studies done for acute respiratory wards patients juxtaposed against the hospitalized COVID-19 positive patients in our institution. Notably, 2 cases of confirmed COVID-19 patients underwent inpatient TTE to evaluate for potential cardiac aetiologies for clinical deterioration. In such cases, focused bedside echocardiographic examinations were performed to assess for cardiac aetiologies of clinical decompensation. The sonographers performing the procedure were properly equipped with PPEs as per protocol and were able to return to their duties the following workday. Importantly, over the past 2 months, none of our 62 staff subsequently developed symptoms suspicious for COVID-19. We could safely perform the clinically indicated echocardiographic examinations for all our patients, irrespective of their COVID-19 status, by implementing the preventive measures described above, with strict adherence to donning of appropriate PPE.

CONCLUSION

The ongoing COVID-19 pandemic has led to healthcare facilities all around the world to adopt highly stringent infectious control measures to prevent further transmission of the disease. Significantly, asymptomatic or pre-symptomatic cases may be prevalent in the community and constitute a “hidden risk” that conventional screening with questionnaires and temperature checks may fail to filter out [23]. Additional measures are thus required to ensure all potential transmissible agents (fomites) or vectors (humans) are mitigated.

While the NHCS echo lab measures may be deemed draconian in otherwise “peaceful” times, an extreme period such as this requires extreme measures. Implementing the “upstream,” “midstream” and “in-stream” control measures have enabled NHCS to avoid case transmissions thus far, and appears to be effective in patient and staff protection during this pandemic.

Supplementary Materials
The online-only Data Supplement is available with this article at https://doi.org/10.22468/cvia.2020.00038.

Conflicts of Interest
The authors have no potential conflicts of interest to disclose.

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