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DESIGN OF NOVEL BABY PERSONAL PROTECTIVE EQUIPMENT: A PORTABLE IOT-BASED BABY PROTECTIVE TENT

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ABSTRACT

Due to the threat of COVID-19 pandemic, personal protection equipment (PPE) has raised lots of attentions to protect people from infection. This unprecedented virus can be spread through airborne, respiratory droplets and social contact. Although there are some devices and PPEs for people who are conscious and able to obey the social distance policy, to protect infants is still challenging. Baby is one of the vulnerable groups to the disease but there is no appropriate PPE when baby needs to be exposed to irresistible events like visiting a hospital, receiving vaccination or being accompanied by parents who come home from work). In this study, a concept of smart baby protective tent is developed. The simple hardware offers a quick assembly using PVC pipes, 3D-printed joints and a transparent cover sheet to create an independent and safe space from direct and indirect infection through breathing or saliva. With two additional parts, the smart baby protective tent can thereby provide clear air circulation and modern care. A fan system equipped with a clamp for a disposable medical-certified mask is applied to supply clean and circulated air for the babies. Functional sensors are attached to detect essential signals like body temperature, environment temperature, humidity, vibration, brightness, sound, CO2, and PM 2.5. These received signals are processed via a micro-controller and can be uploaded to personal social media in order to increase caregivers' awareness of the babies' situation inside the tent.

Keywords: COVID-19, Infant, Personal Protection Equipment

1. INTRODUCTION

COVID-19 has hit our world seriously and caused global pandemic. Not only limited to adults, this novel coronavirus is also infectious to children and babies. In April, cluster infection happened among babies that a Tokyo's baby home reported eight baby infants with coronavirus [1]. The fact is not surprising in related study. For baby infants under 1-year-old, they are prone to infection and severity (10.6%) due to their underdeveloped immune system [2]. Accordingly, preventions for baby infants are essential for parents and caregivers.

Novel coronavirus could be spread so fast due to its extensive routes of transmission, mainly through airborne, respiratory droplets and social contact. In addition to keeping social distance and regular hand-washing, wearing a personal protective equipment (PPE) should be one of the most efficient ways to provide protection when people need to have outdoor or social life. The most common PPE is to wear a mask, however, doesn't apply to baby infants. Due to their immature respiratory system and smaller airways, wearing a mask is risky for them to be suffocated [3].

A hospital in Thailand introduced tiny face shields for baby infants. The shields could adapt to babies' head properly and provide short-term protection [4]. Nevertheless, it's not common

to see baby PPE on the market, even though parents and caregivers are desperately coping with their babies' prevention challenges during the pandemic. Considering baby care and prevention needs, it inspired us to design a specialized infant baby PPE that could protect them from infection and solve the problems of not impeding their regular breath.

In Finland, baby cardboard box is a popular and successful baby care necessity, which the government provided to Finnish parent for each newborn baby. The size of the box could perfectly accommodate one baby and have them feel secure, while it could fulfill the parents' hopes to move the box easily and take care of the babies anywhere at home [5]. The design of baby cardboard box initiated our idea to develop a baby protective tent that could create a secure space for babies with easily accessible materials.

The baby protective tent could be used when there are occasions that babies should be exposed to the public such as go to a doctor or receive vaccination in the hospital. At home, the tent could also be used while the babies are long accompanied by parents or caregivers, who could possibly come home from high-risk environments. The tent could be easily assembled and adapted to baby mattress, stroller or bassinet.

2. MATERIALS AND METHODS

2.1 Configuration of hardware

According to the experience of COVID-19 outbreak, many places over the world cannot always have sufficient support and instant equipment. The intention of baby protective tent is able to quick assembly with common resources and meet the medical requirement. The hardware includes a truss, a cover sheet and a fan system.

The truss is a space for infants to lie down, and the material can be built with PVC pipes and joints. Figure 1 shows the configuration and the dimension is in width 364mm, length 614mm and height 324mm. A transparent sheet is used to cover the framework and plays the role as a shield against direct and indirect infections through breathing or saliva.

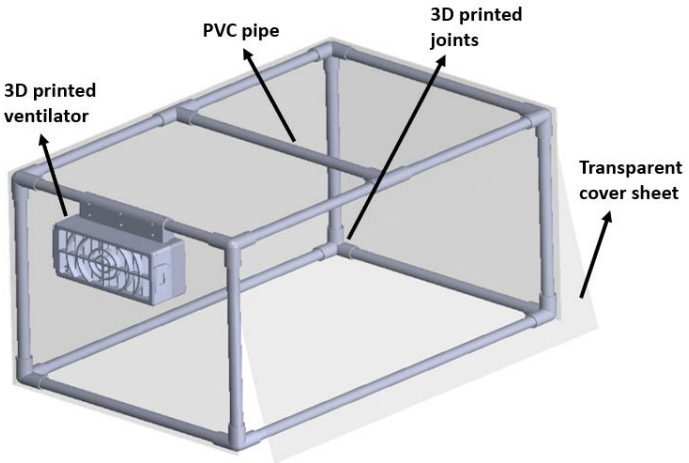

FIGURE 1: THE STRUCTURE AND COMPONENTS OF VENTILATED PROTECTIVE TENT

A fan system is designed for air circulation by supplying a positive air pressure. The case is manufactured by 3D printing and composes two cooler fans inside as a ventilator. The model of cooler fans is 120mm silencio FP R4-SFNL-14PK-R1, provided by Cooler Master Technology Inc. The speed is around 800-1400 RPM with a DC 12 voltage power requirement.

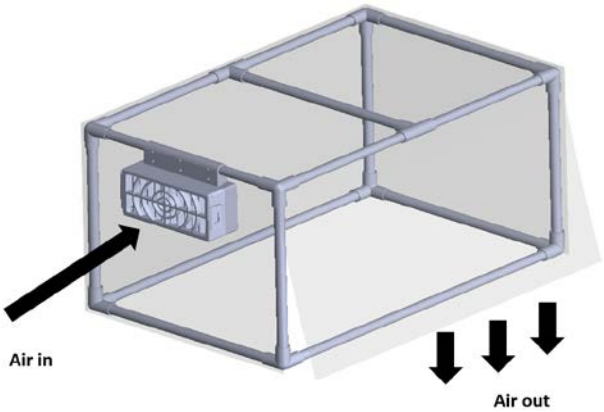

FIGURE 2: THE DESIGN OF THE VENTILATOR ONTO WHICH A MEDICAL CERTIFIED MASK COULD BE APPLIED

When the fan system pumps the air flow into the tent, there is an outlet from the bottom side for air ventilation, as shown in Figure 2. Considering the coronavirus can easily transmit via saliva and air, the fan system clamps a disposable medical-certified mask outside the ventilator (see Figure 3), it works as a HEPA filter that supplies clean air into the baby tent. The advantage of using medical-certified masks is able to be purchased from pharmacy and they are affordable consumables.

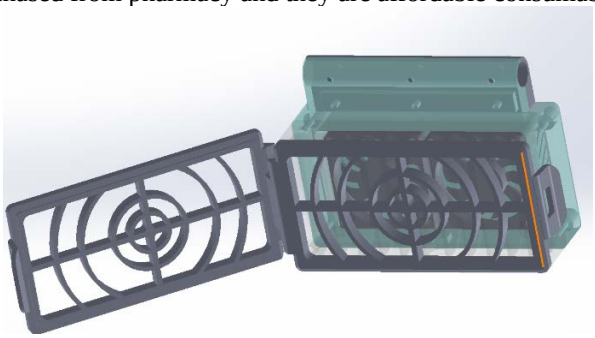

FIGURE 3: THE POSITIVE PRESSURE VENTILATOR SUPPLY CIRCULATED AIR TO THE TENT

2.2 Baby Protective Tent Integrating IoT System

By applying IoT, we empowered the baby protective tent as it could enable the parents or caregivers to monitor the baby's situation and ensure the environment within the tent. The IoT system is composed of wired sensors and a micro-controller that could connect to wifi. The sensors are used to detect signals of

body temperature, environment temperature, humidity, body weight, vibration, brightness, sound, CO2, and PM 2.5. These detected signals will be sent to the micro-controller, then transmitted to the cloud database. Recorded information can be monitored regularly through a designed webpage, providing a history of detection. Additionally, a rule-based algorithm is proceeded on edge side to alarm when any abnormal situation happens, for example body temperature over 37.5 Celsius might occur a fever. The alarm can inform caregivers via social media such as Line, FB. The purpose of integrating IoT system to this baby PPE is for the babies to be cared well and seriously while receiving protection.

2.3 Baby Protective Tent with medical mask

Respiratory droplets are the primary transmission route for SARS-CoV-2. Evidence suggests that virus transmission can be reduced by face coverings with baby tent, but robust evidence for how mask usage might affect safe distancing parameters is lacking. Accordingly, we investigate the effectiveness of medical masks and single-layer cotton masks on mitigating dispersion of large respiratory droplets (i.e. non aerosol). We tested a fluorescent droplet to simulate the coughing conditions. We quantified the number of droplets in flight using laser sheet illumination and UV-light for those that had landed at table height at up to 2m. Our results indicate that face coverings show consistent efficacy at blocking respiratory droplets. If aerosol transmission is later determined to be a significant driver of infection, then our findings may overestimate the effectiveness of face coverings. Figure 4 shows the image of baby tent.

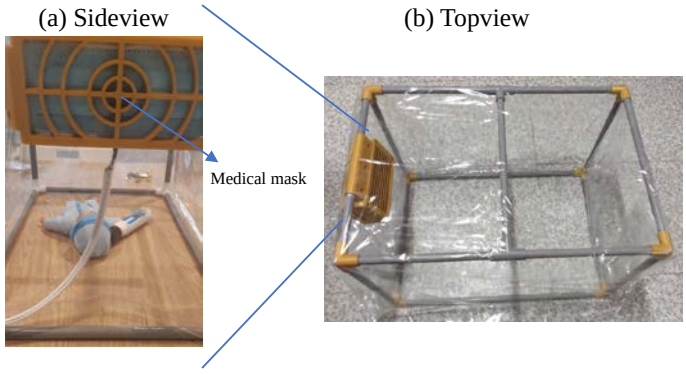

FIGURE 4: (a) THE TENT with MEDICAL MASK (b) THE PHOTO of BABY TENT

3. DISCUSSION AND FUTURE WORK

COVID-19 has changed the way we live and interact with people, not exclusive of the baby infants. Portable and economical PPE should be necessity for everyone not immune to the virus. Moreover, baby care market size keeps growing due to increasing disposable income of families in emerging markets, parents' awareness of baby care quality [6]. As a result, our future work will be to introduce the baby protective tent to the baby care market as a DIY package.

To provide an overview of the spread of droplets over the baby tent, we first used UV light to image the distribution of fluorescent particles that accumulated on white paper placed inside of the tent. An example result for a speaking test is shown in Figure 5. We measured droplet deposition rate according to distance, presented as the number of particles divided by the sampling area and the duration of the experiment by counting the droplets in 15 cm from the tent for speaking. Each experiment was performed six times with and without both types of medical mask, using a new mask for each repeat. The numbers of surface-deposited droplets were consistent with the measurements of falling droplets. Once again, the presence of a face-covering very effectively blocked droplet deposition. However, because we measured droplets on longer duration (up to 20 min) than the flight tests, we could capture less frequent events. An effective method for tracing aerosols is integral to understanding baseline risk and designing mitigation strategies for reducing the transmission risk of SARS-CoV-2. Aerosols that are ≤10 μm are of great importance due to their ability to remain airborne and travel long distances. Particles that are 5 μm or less in diameter can penetrate the lower airways, potentially contributing to an increased severity and likelihood of infection. Figure 5 shows the image of fluorescent droplets distribution.

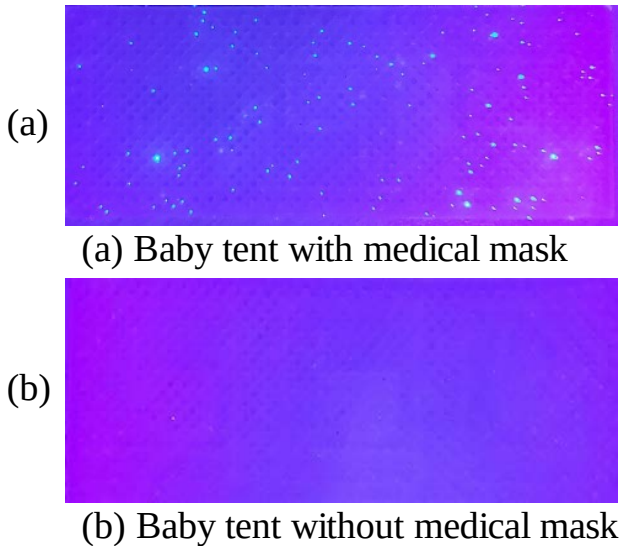

FIGURE 5: Photographs of particulates collected from impactor trials.

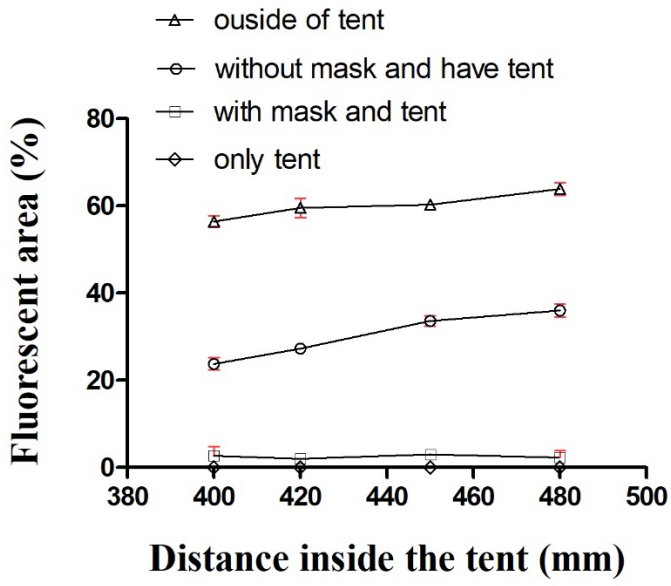

FIGURE 6: Graphs showing that the different conditions to valid the fluorescent droplets distribution.

Figure 6 shows the different conditions to ensure the fluorescent droplets distribution. Our model assessed the potential of dispersing viruses by baby tent with COVID-19. We could not assess the droplets generated during speech by patients infected with COVID-19. Although the real object of interest would be droplet reach/distribution emanating from the patient, the actual spread range of the droplets exhaled by the patient remains unclear. We did not assess aerosols because special tools are needed to visually detect micro-sized droplets. Considering the existence of smaller droplets and aerosols, the actual reach of droplets can expect to be much wider in the clinical setting.

The introduction of the product will be divided into three phases strategically. In the short-term, we open source the ventilated baby protective tent for free as a channel to promote our idea (https://sites.google.com/view/babycare4you), at the same time, to improve our future designs orientating to users' feedbacks. In the medium term, we will introduce baby protective tent integrating IoT system by increasing social media presence, initiating baby care discussions and group buying. In the long term, we plan to provide more service combining our product through alliances with baby care professionals such as pediatric therapist, psychologist, and baby care experts. Furthermore, future versions of baby protective tent could be expected by input of monitoring result data training (machine learning), combining baby care needs and expertise, to enable the tent provide predictive baby care analytics.

4. CONCLUSION

This study demonstrates the development of a novel baby protective tent echoing the urgent needs of parents or caregivers to protect and take care of baby infants during COVID-19 pandemic. The design is going to create value from initial economical version (the ventilated baby protective tent) to better versions evolved with novel applications (the baby protective tent integrating IoT system and algorism) and well-developed business plan.

ACKNOWLEDGEMENTS

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REFERENCES

[1]. Chen H, Guo J, Wang C, Luo F, Yu X, Zhang W, et al. Clinical characteristics and intrauterine vertical transmission potential of COVID-19 infection in nine pregnant women: a retrospective review of medical records. The Lancet 2020;395:809-15.
[2]. Qiu L, Liu X, Xiao M, Xie J, Cao W, Liu Z, et al. SARS-CoV-2 is not detectable in the vaginal fluid of women with severe COVID-19 infection. Clinical Infectious Diseases. 2020; DOI:10.1093/cid/ciaa375.
[3]. Yang Z, Liu Y. Vertical transmission of severe acute respiratory syndrome Coronavirus 2: a systematic review. Am J Perinatol. 2020; DOI:10.1055/s-0040-1712161.
[4]. Di Mascio D, Khalil A, Saccone G, Rizzo G, Buca D, Liberati M, et al. Outcome of coronavirus spectrum infections (SARS, MERS, COVID 1 -19) during pregnancy: a systematic review and meta-analysis. American Journal of Obstetrics & Gynecology MFM 2020;2(2):100-7.
[5]. Yang Z, Wang M, Zhu Z, Liu Y. Coronavirus disease 2019 (COVID-19) and pregnancy: a systematic review. J Matern Fetal Neonatal Med.2020:1-4 DOI:10.1080/14767058.2020.1759541.
[6]. Mehan A, Venkatesh A, Girish M. COVID-19 in pregnancy: risk of adverse neonatal outcomes. J Med Virol. 2020; DOI:10.1002/jmv.25959.