Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Original Research Article

Indian microbiology EQAS registered laboratory’s capacity building and infection control practices during the COVID-19 pandemic in India: Lessons learnt and gaps identified

Malathi Murugesan a,1, Reena Raveendran b,1, Rajesh Kannangai c, Jagadish Ramasamy d, Pallab Ray e, Mallika Gope f, Venkateswaran Natarajan f, Kamini Walia g, Chand Wattal b,**, Balaji Veeraraghavan a,*

a Department of Clinical Microbiology, Christian Medical College, Vellore, Tamil Nadu, India
b Institute of Medical Microbiology and Immunology, Sir Ganga Ram Hospital, New Delhi, India
c Department of Clinical Virology, Christian Medical College, Vellore, Tamil Nadu, India
d Department of Biochemistry, All India Institute of Medical Sciences, Madurai, Tamil Nadu, India
e Department of Medical Microbiology, Postgraduate Institute of Medical Education and Research, Chandigarh, India
f National Accreditation Board for Testing and Calibration Laboratories, Gurugram, Haryana, India
g Indian Council of Medical Research, New Delhi, India

ARTICLE INFO

Keywords:
COVID-19
Laboratory capacity
Infection control

ABSTRACT

Purpose: The COVID-19 pandemic was unique in the history of outbreaks because of the massive scaling up of resources related to diagnostics, treatment modalities, and vaccines. To understand the impact of the pandemic among laboratory professionals, we aimed to conduct a survey to assess the improvement in the lab capacity post-covid in terms of infrastructure and accreditation status across various levels of hospitals and to determine the changes in the practice of infection control precautions during the pandemic.

Methods: This was an anonymous, online-based survey (using 58 item questionnaire) conducted between July 09, 2021, and August 07, 2021. The survey targeted all EQAS registered diagnostic laboratories located in India.

Results: The survey reached out to 1182 participants, out of which 721 (61%) laboratories completed the questionnaire. During pre-COVID times, only 39% (282/721) of the laboratories had an RT-PCR facility. Among these 721 labs, 514 used open system RT-PCR assay, 217 labs used Truenat assay, 188 labs used GeneXpert assay, 31 used Abbott ID Now and 350 labs performed rapid antigen tests. During the pandemic, 55.3% got NABL accreditation and 7.4% were in the process of applying for COVID-19 molecular testing. In this, 80.7% of the laboratories participated in the ICMR COVID quality control assessment. It was estimated that 41.4% of the laboratory professionals were re-using N95 masks. Overall, the infection prevention and control practices varied across each laboratory and hospital.

Conclusion: These survey findings helped us to understand the strength and efficiency of laboratories in India in setting up new assays during a crisis time. Based on our findings, we propose to connect this network in a sustained manner to efficiently utilize the existing platforms to adapt to future pandemics.

1. Introduction

COVID-19 pandemic had been declared a public health emergency of international concern by the World Health Organization in March 2020 [1]. Even though epidemics and pandemics had occurred in the past, a massive scaling up of resources related to diagnostics, treatment modalities, and vaccines that occurred during the COVID-19 pandemic was unique. In India, a network of virus research and diagnostic laboratories (VRDLs) was initiated by the Indian Council of Medical Research (ICMR) to scale up the testing capacity, thereby facilitating early detection, early
containment, and prevention of larger outbreaks [2]. As per the ICMR data, around 1320 Government and 1548 private laboratories conducted diagnostic tests for COVID-19 all over India in August 2021 [3]. During any epidemic outbreaks, laboratories played a key role in strategic testing for early diagnosis and containment of infection [4].

The National Accreditation Board for Testing and Calibration Laboratories (NABL), India, with a mission of initiating new programs supporting accreditation activities, stepped in by pacing up the accreditation process for COVID-19 molecular testing without compromising the quality [5]. As there were newer diagnostic platforms introduced in most of the laboratories during the pandemic, an accreditation process helped in improving the quality of management, reduced the cost, and aided in better control of the operation system.

With this sudden system change in the laboratories, the clinical microbiology laboratories were overwhelmed with respect to laboratory personnel, work timings, infrastructure, and sample overload during the COVID-19 pandemic [6]. The laboratory health care workers (HCW) were at higher risk of acquiring the infection if the infection control practices and disinfection protocol were not followed appropriately. While there was a rampant increase in the number of testing laboratories in India in a year, learning lessons from the pandemic will help us to sustain the practices and be prepared for the future outbreaks. Hence we aimed to conduct an online questionnaire-based survey to understand the perceptions of microbiologists or laboratory HCW during the COVID-19 pandemic. The objectives of this survey were to assess the improvement in the lab capacity post covid in terms of infrastructure and accreditation status across various
levels of hospitals and to determine the changes in the practice of infection control precautions during the pandemic.

2. Material and methods

2.1. Survey conduct

This was an anonymous, online-based survey (using SurveyMonkey®) conducted between July 09, 2021, and August 07, 2021. The participants were invited to take part in the survey through an email with an invitation message and a web link for the survey. The contact details of the laboratories were accessed from the NABL website and the Christian Medical College, Vellore – Sir Ganga Ram Hospital, New Delhi IAMM EQAS program. The survey was accessible only to the participants who gave informed consent. Only one completed response was accepted from each center.

2.2. Questionnaire design

A 58 item questionnaire (Appendix A) was developed and reviewed by all the authors. The majority of the questions were set as closed-ended (yes or no and multiple choice) except for a few open-ended questions. The survey was conducted only in English.

2.3. Statistical analysis

Data were exported to MS Excel® using the SurveyMonkey® platform. The quantitative data was represented in descriptive statistics and all the analyses were done using Microsoft Excel and R programming language.

3. Results

3.1. Demographics

The survey reached out to 1182 participants, out of which 721 (61%) laboratories completed the questionnaire. The average time taken to complete the survey was 11 min. The locations of the participating centers mapped and shown in Fig. 1. Among the laboratories that participated, 75.3% were located in urban, 16.4% in semi-urban and 8.3% were in the rural area. The laboratories were predominantly affiliated with the public sector (73.9%), followed by the Government (24.2%) and a few NGO/mission networks (1.9%). Most of the laboratories were associated with a tertiary care hospital (67.4%), whereas 23.8% were standalone diagnostic centers. The demographic details of the hospitals that participated in the survey shown in Table 1.

3.2. Laboratory capacity and infrastructure

Overall, 82.3% of the laboratories had a computerized laboratory information system and automation facility. During pre-COVID times, only 39% (282/721) of the laboratories had an RT-PCR system being used for routine diagnostic purposes. The remaining 61% (439/721) of the labs set up an RT-PCR testing facility during the pandemic. The COVID-19 testing platforms were newly set up in 535 laboratories by using institutional funding (409/535, 76.45%) and by Government/other grants (126/535, 23.55%). In 186 laboratories, an existing platform was used for COVID-19 testing. Overall, the majority of them reported COVID-19 results within 24 h of turnaround time.

3.3. Diagnostic assays

Overall, 696 out of 721 laboratories responded to the question that aimed to distinguish the type of platform used for COVID-19 testing. 292 (41.9%) laboratories used only one platform for COVID testing. 236 (33.9%) labs used two platforms, 129 (18.5%) labs with three different methods, and 39 (5.7%) labs had more than three methods. Among the diagnostic methods used, 514 labs used open system RT-PCR assay, 217 labs used Truenat® assay, 188 labs used GeneXpert® assay, 31 used Abbott ID Now® and 350 labs performed rapid antigen tests. In these, 54 labs performed only rapid antigen assays. The data on number of samples from rapid antigen assay sent for any confirmatory PCR test was not available. Among these centers, 435 out of 696 (62.5%) of the laboratories performed COVID antibody testing. The most common assay used was CLIA (62.5%) followed by ELISA (31.3%) and the remaining performed other methods.

3.4. NABL accredited medical testing laboratories

Overall, 33.6% of the laboratories were NABL accredited prior to COVID-19 pandemic. When COVID-19 molecular testing accreditation was questioned, 55.3% got accreditation and 7.4% were in the process of application. Among the remaining 37.3% of non-accredited COVID-19 molecular testing labs, 52.1% were private labs, 46.8% were Government institutions and 1.1% were NGO/mission hospital labs. When COVID-19 serological testing accreditation was questioned, 76.1% responded that they did not have accreditation. Owing to an increasing number of mucormycosis cases during the COVID-19 pandemic, a question on fungal testing capability was added, which showed that 81.7% of the labs did not have accreditation for the same.

3.5. Laboratory quality control and assessment

Among the laboratories that participated in the survey, 88.9% used an IVD/FDA-approved diagnostic assay. Of them, 92.4% performed an internal evaluation before implementing the assay in the lab. Most of them (83.6%) performed precision and accuracy testing of their diagnostic method as a part of their routine internal quality assessment. Around 66% of the laboratories were a part of the external quality assessment (EQAS) program run by Christian Medical College Vellore and Sir Ganga Ram Hospital, New Delhi in bacteriology and virology. During the pandemic, 80.7% of the laboratories participated in the ICMR – COVID quality control assessment.

The testing capacity, platforms used, details of accreditation, the impact of the pandemic on these parameters and the lessons learnt had been mentioned in detail in Table 2.
Table 2
Impact of COVID-19 pandemic in laboratory capacity building and accreditation.

| Parameters                                         | Pre COVID | Post COVID | Observation                                                                 | Insights                                                                                                                                 |
|----------------------------------------------------|-----------|------------|------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Availability of RT PCR testing facility in laboratories | 39%       | 61%        | Molecular testing was made available in most of the teaching hospitals and secondary care hospitals during the pandemic. | As laboratory personnel are trained to perform molecular testing, the platform can be utilized to diagnose other bacterial and viral diseases on a routine basis. |
| SARS-CoV2 platform set up                          | NA        | NA         | 25.1% used old platform; 57.3% bought new equipment by institutional funding. | During a short span of time, it was noted that adequate funding was allocated for COVID-19 both from national level and each institutional level. |
| SARS-CoV2 diagnostic assays                        | NA        | NA         | Real time PCR (open) – 41.9% 2 platforms – 33.9% 3 platforms – 18.5% >3 platforms – 5.7% | In future, special budget to be allotted for infection control and outbreak management in national level and in each hospital. |
| SARS-CoV2 antibody tests                           | NA        | NA         | Most of the labs used CLIA (62.5%), ELISA (31.3%) and remaining performed other methods. | Even though multiple methods are available, the cycle threshold (ct) value for reporting positivity differs across each platform which makes the comparability and accuracy of results debatable. |
| NABL accreditation for COVID-19 molecular testing   | NA        | 55.3%      | Antibody targeting the antigens differs across each kits used the labs. | The importance of accreditation and quality of testing to be promoted and guidance to be given to Government and private standalone laboratories. |
| NABL accreditation for COVID-19 serological testing | NA        | 14.7%      | Only 14.7% of the labs performed serological testing. | Training of clinicians in sample collection and processing of samples and identification of fungi for laboratory professionals to be promoted through educational sessions from expert centers. |
| NABL accreditation for fungal testing               | 15.0%     | 3.3%       | Due to increased reporting of mucor cases during COVID-19 pandemic, mucormycosis was included in the notifiable diseases list. |                                             |

NA – Not applicable.

3.6. Infection control practices

When the N95 respirator usage policy was questioned, around 58.6% of the labs followed a single usage policy, 22.5% reused after 72 h of drying, 10.5% reused after 48 h of drying, 5.3% reused after sterilization, and 3% used other methods (Table 2). Most of the laboratories (89.2%) used biosafety level 2 or higher-level safety cabinets for processing COVID-19 samples. As per the biomedical waste management guidelines around 97.28% had an autoclaving facility to treat the laboratory wastes by themselves. When looking at the concentration of sodium hypochlorite used to disinfect COVID-19 wastes, 76.9% used the standard recommendation of 1%, whereas the remaining used varying concentrations in the range of 0.01–5% (Table 3).

The policy of pre-operative screening for COVID-19 varied across the nation, wherein 32.2% performed screening 24 h before surgery, 24.6% used 48 h policy, 21% used a more than 72 h policy and the remaining 22.2% were standalone labs and hence it was not applicable. During the second wave of the pandemic, 19.16% of the hospitals still performed repeat swabbing for discharging the COVID-positive patients. Among the participating centers, 57% of the laboratories followed a one-week quarantine policy after one week of work during the first and second waves. If any exposure occurred for a health care worker, 39.5% of the laboratories followed quarantine for 14 days and testing before joining duty and 24.2% without testing; 19.5% followed 7 days quarantine and testing; 12.4% followed 10 days quarantine and testing and 4.5% followed other policies (Table 3). When asked about COVID-19 vaccination, 74.9% of the laboratories had a mandatory vaccination policy.

4. Discussion

This survey results captured the experience of laboratory professionals during the COVID-19 pandemic in India. It has been observed in our survey that only 8.3% of the participating labs were located in rural areas. Even though the testing facilities were widespread and built up faster in cities, rural parts of India need further improvements in the health care delivery and laboratory infrastructure capacity [7]. 75% of the rural labs were private, 23.3% belong to Government and 1.67% were NGO/Mission centers. During a short span of time, it was noted that adequate funding was allocated for COVID-19 both from national level and each institutional level. This showed that molecular level diagnostic assays can be set up in rural areas. Even though multiple methods are available, the cycle threshold (ct) value for reporting positivity differs across each platform which makes the comparability and accuracy of results debatable.

COVID-19 pandemic has taught us that clinical laboratories and molecular testing play a crucial role in early diagnosis, thereby controlling the spread of cases and the management of the disease [8]. Almost all the laboratories used guidance released by the ICMR in procurement, evaluation, and training.
redeployment, and usage of point of care tests. To cope with the increased number of samples per day, increased manpower, adequate quality testing kits and commodities should be made available in an uninterrupted manner. When large-scale testing is done as a part of public health measures, a validated test kit that is used uniformly across the nation will help in reproducibility and reliability of the results. This has been promising in India as all the testing platforms were validated and approved by the ICMR (Table 4) [9]. Although serological testing was done in many centers across the nation, a validated test kit that is used uniformly across the nation will help in reproducibility and reliability of the results. This has been promising in India as all the testing platforms were validated and approved by the ICMR (Table 4) [9].

Even though the Ministry of Health and Family Welfare, India constantly updates the guidelines based on the new evidence related to SARS-CoV2, the practices differed across each laboratory/institution based on their availability of resources, manpower, and cost. Ideally, N95 mask is defined only for single use; but in this pandemic crisis, it was observed in 33%.

Table 3
Impact of COVID-19 pandemic in IPC practices.

| IPC measures                              | Observation among laboratories/hospitals | Impact                                                                 | Lessons learnt                                                                 |
|-------------------------------------------|-----------------------------------------|----------------------------------------------------------------------|--------------------------------------------------------------------------------|
| N95 mask policy                           | Single usage policy was observed in 58.6%, Re-use after drying for a period of 48-72 h was observed in 33%, Re-use after sterilization in 5.3% | Re-use policy was advised only for FDA approved N95 masks which cannot be made applicable for other varieties of masks. Effectiveness of sterilization for different quality of masks was questionable. | Manufacturing units can be scaled up in India Quality of N95 masks to be tested and certification should be made mandatory Fit testing kits and rational usage of masks should be emphasized |
| Validity period of COVID-19 for pre-operative screening | 24 h before surgery – 32.2%, 48 h before surgery – 24.6%, >72 h before surgery – 21.1%, Not applicable – 22.1% | No standardized national guidelines for universal screening of patients before surgery during the first wave and second wave of pandemic Financial burden for patients due to repeated screening without appropriate rationale and evidence | Nationwide guidelines were released by ICMR during the third wave stating that pre-operative screening for asymptomatic patients is not needed |
| Repeat COVID-19 testing for discharging patients during the second wave | 19.16% repeated COVID-19 test for discharging the patients | Based on the available evidence, the viral shedding has been shown for a prolonged period which will give the test result as positive even if non-infectious. Prolonged period of hospital stay can lead to other complications and secondary infections if COVID negativity is considered as a discharge criterion | ICMR has released guidelines that the repeat COVID testing is not needed for discharging patients Hospitals and public should be aware of the national policies and strict adherence to the policies can be promoted through training sessions and effective communication. |
| Quarantine of health care workers after COVID-19 exposure | Quarantine for 7 days and testing is compulsory before joining duty – 19.5%, Quarantine for 10 days and testing is compulsory before joining duty – 12.4%, Quarantine for 14 days and testing is compulsory before joining duty – 39.5%, Quarantine for 14 days, no testing, can join duty if asymptomatic – 24.2%, Others – 4.5% | Due to manpower constraints, the policy differed across institutions in India. | Judicious use of testing and manpower allocation to be foreseen and strengthened in future pandemics. |
| Vaccination policy among health care workers | 74.9% of the laboratories had mandatory vaccination policy | Overall, the percentage of vaccination was more than 90% among the laboratory professionals | Due to high-risk exposure among laboratory professionals, vaccination should be promoted among all the categories of health care workers. Appropriate/equivalent disinfectants that can disinfect COVID-19 can be tested and certified by national authorities. |
| Disinfection of COVID-19 areas | 76.9% used 1% sodium hypochlorite, Remaining labs/hospitals used varying concentrations between 0.01% and 5% | Long term usage of sodium hypochlorite is found to be corrosive to few surfaces. | Surface compatibility need to be checked and alternate equivalent disinfectants should be added in the policies. |

Accreditation is a process in which an accreditation body (Eg: NABL) awards formal recognition that a body or a person is competent to carry out the scope of diagnostic assays [10]. This accreditation process during the COVID-19 pandemic has helped to improve the accuracy and precision of the reports (Table 4). This will also help to sustain the practices of timely delivery of reports, following SOPs/protocols, adequate training of staff, and practicing quality checks by participating EQAS program. In the remaining non-accredited labs, the importance of accreditation needs to be strengthened through education and awareness.

Even though the Ministry of Health and Family Welfare, India constantly updates the guidelines based on the new evidence related to SARS-CoV2, the practices differed across each laboratory/institution based on their availability of resources, manpower, and cost. Ideally, N95 mask is defined only for single use; but in this pandemic crisis, it was noticed that 41.4% of the laboratory professionals were re-using N95 masks (even in July 2021). This has also been seen in an observational study that showed that only 64% of the HCWs used masks rationally [11]. This can be avoided by maintaining uniformity in the quality and the cost of N95 masks/PPE supply across the country through a testing and certifying body like the FDA [12]. A national-level occupational health and infection control expertise with certification can be enforced in each
surge through mathematical modelling using the con

4.1. Gaps identified in pandemic control measures

The nation-wide network of laboratories helped in predicting the surge through mathematical modelling using the confirmed cases reported to ICMR during the first and the second wave of the pandemic. It was well documented that the SARS-CoV-2 virus can rapidly evolve and mutate so that it can maintain its virulence and can escape from pre-existing immunity obtained from prior infection or vaccination [13]. In this situation, the genomic surveillance played an important role in constantly being vigilant for new strains that evolve in the community. The Indian SARS-CoV-2 Genomic Consortium (INSACOG) launched in January 2020 as in the very early phase of the first wave

4.2. Limitations of the study

Firstly, this survey was conducted before the third wave caused by Omicron strain in India. Hence the results do not reflect the preparedness of laboratories to tackle the enormous testing capacity that was needed during the third wave. Secondly, this study was an invited voluntary survey and hence it did not cover the entire COVID laboratory network in India. Most of the participating laboratories were from Tamil Nadu, Karnataka, Maharashtra followed by Kerala, Uttar Pradesh, Telangana, and West Bengal.

5. Conclusion

The global threat raised by the COVID-19 pandemic had created a high-quality standard molecular laboratory network in India. The lessons learnt during the first wave of the pandemic have made a great difference in operationalizing and managing the second wave in India. These survey findings helped us to understand the strength and efficiency of laboratories in India in setting up molecular assays during a crisis time. This helped in early detection, containment, isolation and management of the patients. Based on our findings, we propose to connect this network in a sustained regular manner for routine diagnostic molecular services and also to efficiently utilize the existing platforms to adapt to future pandemics.

CRediT author statement

Malathi Murugesan: Conceptualization, Methodology, Resources, Validation, Formal analysis, Data Curation, Writing- Original draft & Editing. Reena Raveendran: Conceptualization, Methodology, Resources, Validation, Formal analysis, Writing- Review & Editing. Rajesh Kannanagai: Conceptualization, Resources, Validation, Writing - Review & Editing. Jagadish Ramasamy: Conceptualization, Methodology, Formal analysis, Data Curation, Writing- Review & Editing. Pallab Ray: Conceptualization, Validation, Writing - Review & Editing. Malika Gope: Conceptualization, Resources, Writing - Review & Editing. Venkateswaran Natrajan: Conceptualization, Resources, Writing - Review & Editing. Kamini Walia: Conceptualization, Writing - Review & Editing. Pallab Ray: Conceptualization, Validation, Writing - Review & Editing. Nabil Ameen: Conceptualization, Methodology, Resources, Validation, Data Curation, Writing - Review & Editing.

Ethics approval

The EQAS activity was granted exemption from ethical clearance by “Institutional Review Board” from Christian Medical College, Vellore, India and granted ethical clearance from Sir Ganga Ram Hospital, New Delhi.

Funding

None.
Conflicts of interest

None.

Acknowledgments

The authors sincerely acknowledge Dr. Venkata Raghava Mohan and Dr. Chella Sindhu from Department of Community Health, Christian Medical College, Vellore for doing a critical review of our questionnaire.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijmmb.2022.09.009.

References

[1] COVID-19 public health emergency of international concern (PHEIC) global research and innovation forum [Internet]. [cited 2021 Nov 23]; Available from: https://www.who.int/publications/m/item/covid-19-public-health-emergency-of-international-concern-pheic-global-research-and-innovation-forum.

[2] Gupta N, Potdar V, Praharaj I, Giri S, Sapkal G, Yadav P, et al. Laboratory preparedness for SARS-CoV-2 testing in India: harnessing a network of virus research & diagnostic laboratories. Indian J Med Res 2020;151(2 & 3):216–25.

[3] COVID_Testing_Labs_13082021.pdf [Internet]. [cited 2021 Aug 14]; Available from: https://www.icmr.gov.in/pdf/covid/labs/COVID_Testing_Labs_13082021.pdf.

[4] Lippi G, Mattiucci C, Pibani M. Laboratory preparedness to face infectious outbreaks. Ebola and beyond. Clin Chem Lab Med 2014;52(12):1681–4.

[5] Vision and Mission [Internet]. Nabl India 2016 [cited 2021 Aug 14]; Available from: https://nabl-india.org/about-nabl/vision-and-mission/.

[6] Clinical microbiology laboratories and COVID-19: the calm before the storm [Internet]. [cited 2021 Aug 14]; Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7675011/.

[7] Kumar A, Rajasekharan Nayar K, Koya SF. COVID-19: challenges and its consequences for rural health care in India. Public Health in Practice 2020;1:100009.

[8] Tomo S, Karli S, Dharmalingam K, Yadav D, Sharma P. The clinical laboratory: a key player in diagnosis and management of COVID-19. EJIFCC 2020;31(4):526–46.

[9] Diagnostic Kit Evaluation [Internet] [cited 2021 Nov 18]; Available from: https://www.icmr.gov.in/dkitevaluation.html.

[10] Wadhwa V, Rai S, Thukral T, Chopra M. Laboratory quality management system: road to accreditation and beyond. Indian J Med Microbiol 2012;30(2):131–40.

[11] Supehia S, Singh V, Sharma T, Khapre M, Gupta PK. Rational use of face mask in a tertiary care hospital setting during COVID-19 pandemic: an observational study. Indian J Publ Health 2020;64(6):225.

[12] Health C for D and R. Personal Protective Equipment EUAs. FDA [Internet] 2021 [cited 2021 Nov 23]; Available from: https://www.fda.gov/medical-devices/coronavirus-disease-2019-emergency-use-authorizations-medical-devices/personal-protective-equipment-euas.

[13] Weisblum Y, Schmidt F, Zhang F, DaSilva J, Poston D, Lorenzi JC, et al. Escape from neutralizing antibodies by SARS-CoV-2 spike protein variants. elife 2021;9:e61312.

[14] INSACOG | Department of Biotechnology [Internet]. [cited 2022 Apr 12]; Available from: https://dbtindia.gov.in/insacog.