Nuclear Cardiology Practice in Asia: Analysis of Radiation Exposure and Best Practice for Myocardial Perfusion Imaging — Results From the IAEA Nuclear Cardiology Protocols Cross-Sectional Study (INCAPS) —

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Background: This paper examines the current status of radiation exposure to patients in myocardial perfusion imaging (MPI) in Asia.

Methods and Results: Laboratories voluntarily provided information on MPI performed over a 1-week period. Eight best practice criteria regarding MPI were predefined by an expert panel. Implementation of ≥6 best practices (quality index [QI] ≥6) was pre-specified as a desirable goal for keeping radiation exposure at a low level. Radiation effective dose (ED) in 1,469 patients and QI of 69 laboratories in Asia were compared against data from 239 laboratories in the rest of the world (RoW). Mean ED was significantly higher in Asia (11.4 vs. 9.6 mSv; P<0.0001), with significantly lower doses in South-East vs. East Asia (9.7 vs. 12.7 mSv; P<0.0001). QI in Asia was lower than in RoW. In comparison with RoW, Asian laboratories used thallium more frequently, used weight-based technetium dosing less frequently, and trended towards a lower rate of stress-only imaging.

Conclusions: MPI radiation dose in Asia is higher than that in the RoW and linked to less consistent use of laboratory best practices such as avoidance of thallium, weight-based dosing, and use of stress-only imaging. Given that MPI is performed in Asia within a diverse array of medical contexts, laboratory-specific adoption of best practices offers numerous opportunities to improve quality of care.

Key Words: Best practice; Myocardial perfusion imaging; Nuclear cardiology; Radiation

It has been estimated that half of the world’s burden of cardiovascular diseases is carried by the Asia-Pacific region,\(^1,2\) underscoring the critical role of the diagnosis, prevention, and treatment of cardiovascular disease in this region.\(^3\) Nuclear myocardial perfusion imaging (MPI) is extensively used for the evaluation of known or suspected coronary artery disease (CAD), with an estimated 15–20 million procedures performed annually worldwide.\(^4\) It has...
been proven as a cost-effective tool for the evaluation and management of cardiac patients, often playing a decisive role in diagnosis, prognosis, risk stratification, as well as guidance of therapy. Clinical scenarios in which nuclear cardiology (NC) can be helpful are continuously expanding. Concomitantly, radiation exposure due to medical practices, to which cardiac imaging contributes, is a growing concern, with its several-fold increase in the last 3 decades. In some populations now, MPI is the procedure contributing most to radiation doses. Several steps have been taken to address this problem, such as emphasizing lower-dose protocols, and the introduction of technological approaches such as gamma-cameras with solid state detectors, and more efficient image reconstruction algorithms. The American Society of Nuclear Cardiology (ASNC) established a series of recommendations with the aim of reducing median radiation effective dose (ED) to ≤9 mSv. Pursuant to its mission, the International Atomic Energy Agency (IAEA) has long played a focal role in the dissemination and promotion of nuclear medicine, with a special focus on applications in cardiology throughout its Member States. This has been accomplished by means of educational and training initiatives, such as regional training courses supported by the IAEA Technical Cooperation Program, as well as through fellowships provided to nuclear medicine or cardiology practitioners who want to improve their clinical competence in the field of NC.

Given that radiation exposure due to medical practices, to which cardiac imaging contributes, is a growing concern, the IAEA Nuclear Cardiology Protocols Study (INCAPS) was launched with the aim of characterizing NC practice worldwide, with a focus on MPI and radiation exposure to patients undergoing MPI. This paper provides a snapshot of the practice of NC in Asia, presenting INCAPS results in Asia, and identifies areas of possible intervention to optimize patient radiation exposure due to NC procedures.

| No. | Best practice | Basis |
|-----|---------------|-------|
| 1   | Avoid 201Tl stress | SPECT with 201Tl is associated with a considerably higher radiation dose to patients than 99mTc. This practice excludes 201Tl viability studies and stress redistribution-reinjection stress-and-viability studies. |
| 2   | Avoid dual isotope imaging | Dual isotope imaging is associated with the highest radiation dose of any protocol. |
| 3   | Avoid use of too much 99mTc | 1,332 MBq is the highest recommended activity in guidelines, and 15 mSv is a very high radiation dose for 99mTc. |
| 4   | Avoid use of too much 201Tl | The expert committee maintained that 129.5 MBq should be the upper threshold for 201Tl activity. |
| 5   | Perform stress-only imaging | If stress images are completely normal, subsequent rest imaging can be omitted. |
| 6   | Use camera-based dose-reduction strategies | Each of these approaches reduces the activity needed and facilitates performance of stress-only imaging. |
| 7   | Use weight-based dosing for 99mTc | Tailoring the activity to patient weight offers an opportunity to reduce radiation dose. |
| 8   | Avoid inappropriate dosing that can lead to "shine-through" artefact | Shine-through occurs in 1-day 99mTc when residual radioactivity from the first injection interferes with the images following the second injection. To avoid shine-through, guidelines recommend that the activity of the second injection should be 3–4-fold higher than that of the first injection. A second injection with an activity <3-fold the activity of the first injection can lead to shine through. |

Adapted from Lindner et al. SPECT, single-photon emission computed tomography.

**Methods**

**Study Design and Focus**

This study was conceptualized following expert and stakeholder meetings organized by the IAEA since February 2012 (participant list given in Appendix 1) aimed at improving NC practice worldwide. INCAPS was designed as a study with a specific focus on the current status of NC practice worldwide and an emphasis on MPI and the corresponding radiation exposure.

A survey instrument was emailed to all nuclear medicine centers performing NC MPI registered in the IAEA database, as well as to the entire database of local and international nuclear medicine, cardiology and related professional organizations and INCAPS coordinators. Voluntary in nature, it asked respondents to provide information on patients undergoing MPI between the weeks beginning 19 March and 22 April 2013 (inclusive), and answer questions related to tracer utilization, dosage/doses used and the technology available. Data received from responders worldwide were checked for accuracy of information and, if necessary, clarifications were made. Potential participants were approached and provided with data collection forms. Active participants were not pre-selected but rather voluntarily agreed to contribute to the study.

Data collection included demographics; weight; radiopharmaceutical(s) used; radiopharmaceutical dosage; and type of study protocol (i.e., single-day/2-day or stress-only protocol for 99mTc/99 compounds). All data were collected in compliance with the Columbia University Institutional Review Board, which approved this study, deeming it exempt from the requirements of US federal regulations for the protection of human subjects (Code of Federal Regulations, Title 45, Part 46) because no individually identifiable health information was collected. Worldwide, a total of 308 laboratories responded, and ED estimates, and adherence to best practice in NC, were the main parameters measured to establish comparisons of variations in NC between the 69 participant laboratories from Asia and the remaining 239 from the rest of the world (RoW).

**ED Estimation**

ED (in mSv) is defined by the International Commission on Radiological Protection as “the weighted sum of the equivalent doses in all specified tissues and organs of the human body and [which] represents the stochastic health risk to the whole body, which is the probability of cancer induction and genetic effects, of ionising radiation.”
Radiation dose was calculated according to models of the International Commission on Radiological Protection. Following the ASNC recommendation to attain a median ED $\leq$9 mSv by 2014, we considered the proportion of patients and laboratories achieving this goal as a benchmark for best practice.

Best Practice
In an attempt to identify the best approach to individual dose optimization in NC, experts, including physicians and medical physicists, convened for an IAEA meeting, to identify and define 8 best practices in NC. Based on a review of published guidelines, the panel determined best practice as follows. (1) Avoidance of 201Tl stress; (2) avoidance of dual isotope imaging; (3) avoidance of too much 99mTc; (4) avoidance of too much 201Tl; (5) performance of stress-only imaging; (6) use of camera-based dose-reduction strategies; (7) use of weight-based dosing for 99mTc; and (8) avoidance of inappropriate dosing that can lead to “shine-through” artefact (Table 1). More details regarding these practices are reported elsewhere. Those criteria were included in the study design, before its launch, as well as a quality index (QI) score, equal to the number of best practices adhered to by a laboratory. Implementation of at least 6 of those 8 best practices (QI $\geq$6) was pre-specified as a desirable goal for keeping radiation exposure low. Best practices and the quality score were considered at the individual laboratory level.

Statistical Analysis
For the purpose of this study, data have been extracted from the overall INCAPS study and analyzed for the Asia region overall, as well as for subregions, in accordance with the United Nations Geoscheme. These subregions are West Asia (Israel, Kuwait, Saudi Arabia, Turkey, United Arab Emirates), South Asia (Bangladesh, India, Iran, Pakistan, Sri Lanka), East Asia (China, Japan, South Korea) and South-East Asia (Indonesia, Philippines, Singapore, Thailand, Vietnam). Practice variables and ED, at both the patient and laboratory level, are compared with the RoW.

The full description of statistical methods has been published previously. Briefly, statistical analysis focused on the calculated patient ED and the corresponding adherence to identified best practice and the QI score differences between the Asian regions and subsequently with the RoW. Continuous variables were compared using Student’s t-test or analysis of variance for calculated means, and Kruskal-Wallis test for calculated medians. The comparison of mean ED among Asian regions, and between Asia and the RoW was adjusted for patient weight using analysis of variance. Chi-squared test was used to compare...
Effective Dose

Looking at Asia as a whole, ED was significantly higher than in the RoW (11.4 vs. 9.6 mSv; P<0.0001). This difference remained after adjustment for patient weight (P<0.0001). Figures 2,3 show the distribution of ED observed, demonstrating considerable variability in ED in all regions, with modest but significant differences in ED among Asian subregions and between Asia and RoW. Fewer Asian patients and laboratories achieved doses ≤ 9 mSv compared with the RoW, with differences across Asia, and this goal was achieved more frequently in South-East Asia (Table 3).

Protocols

Patients underwent a stress-only protocol more frequently in Asia than in the RoW. Across the region, 272 (18%) underwent this protocol as opposed to 733 (11%) in the RoW (P<0.001). Again there were significant variations among the subregions: South Asia applied this protocol in 78 patients (11%); East Asia in 13 patients (5%); South-East Asia in 76 patients (25%) and West Asia in 105 patients (22%; P<0.001). The use of 201Tl was more frequent in Asia than in the RoW (11%, 195/1,469, vs. 1.5%, 98/6,442 in the RoW) whereas the use of positron emission tomography appeared more limited: 52 patients in Asia (3.5%) vs. 418 (6.5%) in the RoW. Among Asian patients, 298 of 1,469 patients had 201Tl (e.g., 201Tl or dual isotope) vs. 147 of 6,442 in the RoW (P<0.0001). On a laboratory categorical variables. All analysis was performed using Stata/SE 13.1 (StataCorp, College Station, TX, USA), and P<0.05 was considered statistically significant.

## Results

### Demographics

Out of a total of 308 laboratories participating in this study worldwide, 69 labs from Asia reported on a total of 1,469 patients (Figure 1). Mean age was 61.8±12.5 years, significantly lower for Asia compared with the RoW (P<0.0001). Out of those patients 559 were female (38%), 482 (33%) were from the West subregion, 310 (21%) from the South-East, 272 (18.5%) from the East, and the remaining 405 (27.5%) were from the South (Table 2).

### Effective Dose

Looking at Asia as a whole, ED was significantly higher than in the RoW (11.4 vs. 9.6 mSv; P<0.0001). This difference remained after adjustment for patient weight (P<0.0001). There was a statistically significant difference in ED between the Asian subregions, with lower doses noted in South-East Asia (Table 3). Again, this difference was maintained after adjustment for patient weight (P<0.0001). Figures 2,3 show the distribution of ED observed, demonstrating considerable variability in ED in all regions, with modest but significant differences in ED among Asian subregions and between Asia and RoW. Fewer Asian patients and laboratories achieved doses ≤ 9 mSv compared with the RoW, with differences across Asia, and this goal was achieved more frequently in South-East Asia (Table 3).
On a laboratory-basis analysis for the Asia region, the proportion of laboratories adhering to ≥6 best practices is 18/69 (26%), significantly smaller than in the RoW, where 124/239 laboratories had QI ≥6 (52%; P<0.001; Table 4). This low proportion in Asia is due mainly to the limited implementation of 2 best practices, namely the avoidance of thallium stress testing in patients <70 years and weight-based dosing for technetium, which are used less frequently than in the RoW. Of note, the practice of using thallium stress in patients <70 basis, 51 laboratories performed at least 1 study with $^{201}$Tl, 26 of which were in Asia (26/69 in Asia vs. 25/239 in RoW; P<0.0001).

**Best Practices and QI**

Use of individual best practices in the 69 Asian laboratories is shown in Table 4. Overall, 18/69 Asian laboratories (26%) achieved QI ≥6 vs. 124/239 (52%) in the RoW (P<0.001).

**Discussion**

As an independent United Nations intergovernmental organization, the IAEA develops radiation and nuclear safety standards and, based on these standards, promotes the achievement and maintenance of high levels of safety in applications of atomic energy, such as in the protection of human health. One of the means to ensure that patient radiation exposure is kept “as low as reasonably achievable” (ALARA principle) is to foster and promote training and education in fields such as NC, something that the Agency has pursued actively in the last decade (Figure 4). A total of 1,071 participants were trained through 41 regional training courses conducted in NC. Recognition of these efforts and their costs has triggered attempts to measure the outcome of those activities. To this aim, some projects are underway and 1 of these has been the INCAPS study.

The worldwide analysis of the INCAPS data demonstrated variations with regards to adherence to best practices and patient radiation dose. Regional analyses have been also performed for Europe, Latin America, the USA, Africa, and Oceania. On a laboratory-basis analysis for the Asia region, the proportion of laboratories adhering to ≥6 best practices is 18/69 (26%), significantly smaller than in the RoW, where 124/239 laboratories had QI ≥6 (52%; P<0.001; Table 4). This low proportion in Asia is due mainly to the limited implementation of 2 best practices, namely the avoidance of thallium stress testing in patients <70 years and weight-based dosing for technetium, which are used less frequently than in the RoW. Of note, the practice of using thallium stress in patients <70 years is a significant contributor to patient radiation dose.

![Figure 2](image-url). Effective dose from myocardial perfusion imaging vs. region.
Figure 3. Distribution of myocardial perfusion imaging effective dose vs. Asia subregion.

Table 4. (A) Best Practices Used, and (B) Laboratory QI

| Asia Subregions¹ | South Asia | East Asia | South-East Asia | West Asia | P-value | Asia total vs. RoW | P-value |
|------------------|------------|-----------|-----------------|-----------|---------|-------------------|---------|
| Laboratories     | 16 (23)    | 16 (23)   | 20 (29)         | 17 (25)   |         | 69 (23)           | 239 (77) |
| Best practice    |            |           |                 |           |         |                   |         |
| Avoid thallium stress | 13 (81)   | 14 (88)   | 13 (65)         | 12 (71)   | 0.44    | 52 (75)           | 230 (96) | <0.001 |
| Avoid dual isotope | 14 (88)   | 14 (88)   | 20 (100)        | 16 (94)   | 0.33    | 64 (93)           | 234 (98) | 0.049  |
| Avoid too much technetium | 15 (94)   | 14 (88)   | 18 (90)         | 17 (100)  | 0.61    | 64 (93)           | 199 (83) | 0.054  |
| Avoid too much thallium | 16 (100)  | 16 (100)  | 20 (100)        | 16 (94)   | 0.71    | 68 (99)           | 238 (100) | 0.40   |
| Perform stress-only imaging | 4 (25)    | 0 (0)     | 3 (15)          | 9 (53)    | 0.002   | 16 (23)           | 77 (32)  | 0.15   |
| Use camera-based dose-reduction strategies | 11 (69)   | 12 (75)   | 15 (75)         | 10 (59)   | 0.75    | 48 (70)           | 158 (66) | 0.59   |
| Weight-based dosing for technetium | 1 (6.3)   | 0 (0)     | 3 (15)          | 4 (24)    | 0.18    | 8 (12)            | 80 (33)  | <0.001 |
| Avoid “shine through” dosing | 5 (31)    | 6 (38)    | 9 (45)          | 6 (35)    | 0.88    | 26 (38)           | 110 (46) | 0.22   |

| Laboratories, n (%) | 16 (23) | 16 (23) | 20 (29) | 17 (25) | 69 (23) | 239 (77) |
|---------------------|---------|---------|---------|---------|---------|---------|
| QI (target ≥6)      |         |         |         |         |         |         |
| Mean±SD             | 4.9±0.9 | 4.8±0.9 | 5.1±1.4 | 5.3±1.2 | 0.57    | 5±1.1   | 5.5±1.3 | 0.002 |
| Median              | 5       | 5       | 5       | NA      | 5       | 5       | NA      |       |
| IQR                 | 4–5.5   | 4.5–5   | 4–6     | 4–6     | 4–6     | 5–6     | 5–6     |       |
| QI ≥6, n (%)        | 4 (25)  | 2 (12)  | 6 (30)  | 6 (35)  | 0.52    | 18 (26) | 124 (52) | <0.001 |
| QI (0–8), n (%)     | 2       | 0       | 0       | 0       | 0       | 2       | 1       |
|                     | 3       | 0       | 2 (13)  | 2 (10)  | 0       | 4 (6)   | 11 (5)  |
|                     | 4       | 6 (38)  | 2 (13)  | 5 (25)  | 5 (29)  | 18 (26) | 38 (16) |
|                     | 5       | 6 (38)  | 10 (63) | 7 (35)  | 6 (35)  | 29 (42) | 64 (27) |
|                     | 6       | 3 (19)  | 2 (13)  | 4 (20)  | 3 (18)  | 12 (17) | 70 (29) |
|                     | 7       | 1 (6)   | 0       | 0       | 2 (12)  | 3 (4)   | 35 (15) |
|                     | 8       | 0       | 0       | 2 (10)  | 1 (6)   | 3 (4)   | 19 (8)  |

Data given as n (%). †West Asia: Israel, Kuwait, Saudi Arabia, Turkey, United Arab Emirates; South Asia: Bangladesh, India, Iran, Pakistan, Sri Lanka; East Asia: China, Japan, South Korea; South-East Asia: Indonesia, Philippines, Singapore, Thailand, Vietnam. QI, quality index; RoW, rest of the world.
years occurs in 25% of laboratories in Asia and is consistent across all Asian subregions with no statistically significant difference. With regard to patient-level ED calculation, the median ED for 201Tl was virtually identical between Asia and the RoW, whereas median ED was higher in Asia for 99mTc (Table 3), notwithstanding the considerably heavier weights of RoW patients, who weighed >10kg than their Asian counterparts on average (Table 2). These findings probably reflect several factors, including less concern among Asian laboratories regarding avoidance of thallium and dual isotope stress testing, their significantly lower use of weight-based 99mTc dosing (12% vs. 33%), and a generally less careful approach to dose optimization. This raises a red flag with respect to the potential inappropriate use of this radiopharmaceutical and further confirms its continued use in the laboratories in the region, while it is almost abandoned in the RoW, where only 4% of laboratories still use thallium stress testing (Table 4), probably due to its considerably higher radiation dose and poorer spatial resolution.

Many societal factors likely contribute to the variations in ED and QI observed among Asian countries, which reflect a diverse array of developed and developing societies. Differences in education, human resources, technological resources available, health policy, and medical economy all could contribute to these findings. In terms of education, both the nature of medical training and initiatives for continuous professional development and continuous medical education (CPD/CME) are important. In the absence of updated CPD/CME opportunities, requesting physicians can still refer for 201Tl stress, dual isotope imaging and other deviations from the best practices in NC, which contributes to higher patient ED. Adherence to at least 6 of the best practices in NC will significantly reduce unnecessary radiation exposure. Determination of adherence to these best practices provides an opportunity for each laboratory to identify its own areas for potential improvement. Appropriate CPD/CME opportunities focused on the 8 best practices in NC should be made available in order to harmonize or standardize appropriate MPI use.

One of the possible explanations for the persistence of inappropriate 201Tl studies in Asia compared with the RoW could be that the nomenclature “stress thallium” is still embedded into referring physician culture as a synonym for MPI, and laboratories do not question this referral. Another possible explanation could be that, particularly in remote areas, availability of 99mTc (or reliability of generator arrival) may be an issue and as such, thallium protocols may be an easier default. In a survey conducted by the IAEA in 2011, operating nuclear medicine centers worldwide were asked to rate the efficiency of their centers in responding to requests from referring physicians. The Asian region was found to have maximum efficiency, translated into more procedures performed per referring physician request. The longer physical half-life of thallium (73h vs. 6h for 99mTc), while resulting in higher radiation dose, may facilitate its availability, reflected by this better availability of nuclear imaging services in some Asian centers. In any event, the reasons why thallium stress testing is used more frequently in Asia than elsewhere should be further investigated, to fulfill the twin goals of facilitating best practice use and minimizing radiation dose in NC.

With regards to scaling patient dose to weight, this practice is also not widely implemented in Asia. This is done in only 11% of centers, evenly distributed in the 4 subregions, as opposed to 33% worldwide. One reason could be that most laboratories in Asia receive their radiopharmaceuticals as unit doses from commercial centralized radioisotopes, which tend to dispense unit doses with predefined activities (i.e., 10–15mCi for rest and 30–40mCi for stress studies). A laboratory where tests are performed may not proceed further to dose adjustment before the test is done, perhaps due to lack of equipment, skill or simply for practicality or convenience. Insurance regulations in some countries of Asia, which request fixed doses rather than weight-based dosing, is another possible reason. This deviation in practice should be further investigated in order to plan appropriate and adequate interventions to improve NC practice. This is all reflected in the higher radiation exposure for Asian patients, who receive a 2mSv higher dose on average compared with the RoW, notwithstanding being lighter than patients elsewhere. This higher radiation exposure is linked to a greater usage of dual isotope and thallium stress protocols, as well as more limited implementation of weight-based dosing when 99mTc is utilized as discussed here. There is, however, a significant variation within the region, in that the number of patients in South-East Asia (Indonesia; Philippines; Singapore; Thailand; Vietnam) who have received >9mSv is significantly smaller (P<0.001) than in the other subregions, while those from East Asia (China; Japan; South Korea) receive on average 12.7mSv. This offsets the finding that Asian patients are more likely to undergo a stress-only 99mTc protocol, which in principle should carry with it a lower ED because the rest injection is not given. Again, in the wide Asian region there are significant differences between the subregions, with patients from East Asia being the least likely to undergo a stress-only protocol. One possible explanation is that this is simply due to fewer patients with a low likelihood of CAD being studied in the East. Between the Asian subregions, aside from the other deviations from the best practices noted, variation in the average ED might also be attributed to differences in the level of enforcement of existing directives geared towards radiation exposure due to medical reasons. Unlike Europe, the Asian region as a whole lacks a common directive approach, such as the
Circulation Journal Vol. 81, April 2017

3, due to 2 best practices, viz. “perform stress-only imaging” and “weight-based dosing for technetium”, being least used. Stress-only imaging, in particular, has been shown to reduce radiation exposure, as reflected in a study looking at stress-only imaging in the INCAPS population.36

Finally, considering the long-lasting efforts of the IAEA on training activities in NC in 2005–2015 (Figure 4), there is clearly a need to provide greater focus on best practice to improve the quality of cardiac imaging and minimize radiation exposure to patients.28 34 36

Study Limitations
Several limitations exist in this study. Due to the voluntary nature of the survey, 308 laboratories were enrolled in the study worldwide, 69 of which were from Asia, a number that is far lower than the actual number of Asian clinics performing MPI. Given, however, that the exact number of clinics is unknown, it would be difficult to predict to what extent these centers are representative of current MPI practice. Although the modest number of centers studied here may limit the generalizability of the findings, they provide the baseline and a framework for further research involving more centers and patients in individual Asian countries. Building on this research, successive initiatives can include more participants and provide a more complete picture of the nature of nuclear practice.

Crucial socioeconomic factors such as the economic and technological resources available, health policy, nature of medical training and initiatives for CPD/CME, are all likely to have an influence on variation in medical practice in general and NC practice in particular. The present study did not collect data to assess the impact of such factors on NC practices, but their further investigation is needed in future research.

Additionally, while the countries and subregions are geographically close, they are nevertheless very different and do not share language, resources or educational opportunities. The lumping of countries by regions, although a practical necessity, dilutes the significant variations that may exist even among neighbors in the same region and within individual countries. Finally, given that the focus was on radiation exposure, other important aspects of MPI practice were not investigated, including, but not limited to, justification/appropriateness and quality of imaging.

Conclusions
In this study of MPI practice in Asia and worldwide, we observed marked variation in radiation dose and in the use of best practices impacting radiation dose. In comparison with the RoW, Asian laboratories were characterized by higher average radiation dose despite lower patient weight, more frequent use of thallium, less use of weight-based technetium dosing, and a trend towards a lower rate of stress-only imaging. Although involving a diverse array of societies, significant differences were noted between regions of Asia. Laboratory-specific identification of best practices non-adherence, and interventions targeted at implementing best practices, offer Asian laboratories numerous opportunities to improve the quality of NC care across the continent.

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