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Semi-Quantitative Scoring of Late Gadolinium Enhancement of the Left Ventricle in Patients with Ischemic Cardiomyopathy: Consensus Statement from the Asian Society of Cardiovascular Imaging-Practical Tutorial (ASCI-PT) 2020

Chul Hwan Park[1]*, Cherry Kim[2]*, Bae Young Lee[3], Chan Ho Park[4], Eun-Ju Kang[5], Hyun Jung Koo[6], Kakuya Kitagawa[7], Min Jae Cha[8], Rungroj Krittayaphong[9], Sang Il Choi[10], Sanjaya Viswamitra[11], Sung Min Ko[12], Sung Mok Kim[13], Sung Ho Hwang[14], Nguyen Ngoc Trang[15], Whal Lee[16], Young Jin Kim[17], Jongmin Lee[18], Dong Hyun Yang[6]

[1]Department of Radiology and Research Institute of Radiological Science, Gangnam Severance Hospital, Yonsei University College of Medicine, Seoul, Korea
[2]Department of Radiology, Korea University Ansan Hospital, Ansan, Korea
[3]Department of Radiology, Eunpyeong St. Mary's Hospital, College of Medicine, The Catholic University of Korea, Seoul, Korea
[4]Department of Radiology, Soonchunhyang University Cheonan Hospital, Cheonan, Korea
[5]Department of Radiology, College of Medicine, Dong-A University, Busan, Korea
[6]Department of Radiology and Research Institute of Radiology, Cardiac Imaging Center, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea
[7]Department of Radiology, Mie University Graduate School of Medicine, Tsu, Japan
[8]Department of Radiology, Chung-Ang University Hospital, Seoul, Korea
[9]Division of Cardiology, Department of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand
[10]Department of Radiology, Seoul University Bundang Hospital, Seongnam, Korea
[11]Department of Radiology, Sri Sathya Sai Institute of Higher Medical Sciences, Karnataka, India
[12]Department of Radiology, Yonsei University Wonju College of Medicine, Wonju Severance Christian Hospital, Wonju, Korea
[13]Department of Radiology, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea
[14]Department of Radiology, Korea University Anam Hospital, Seoul, Korea
[15]Center of Radiology, Bachmai University Hospital, Hanoi, Vietnam
[16]Department of Radiology, Seoul University Hospital, Seoul, Korea
[17]Department of Radiology and Research Institute of Radiological Science, Severance Hospital, Yonsei University College of Medicine, Seoul, Korea
[18]Department of Radiology, Kyungpook National University Hospital, Daegu, Korea

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Corresponding author
Dong Hyun Yang, MD
Department of Radiology and Research Institute of Radiology, Cardiac Imaging Center, Asan Medical Center, University of Ulsan College of Medicine, 88 Olympic-ro 43-gil, Songpa-gu, Seoul 05505, Korea
Tel: 82-2-3010-5820
Fax: 82-2-476-8127
E-mail: donghyun.yang@gmail.com

*These authors contributed equally to this work.

The Asian Society of Cardiovascular Imaging-Practical Tutorial (ASCI-PT) is an educational program of the ASCI School, which was founded in 2019. In 2020, ASCI-PT was held from November 23rd to 25th for the purpose of creating a consensus statement on semi-quantitative scoring for late gadolinium enhancement (LGE) in patients with ischemic cardiomyopathy. Eighteen panelists from five countries meticulously reviewed the existing guidelines and addressed seven issues to improve the communication of LGE interpretation and reduce inter-observer

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variability. All panels participated in online or offline sessions to build a consensus on LGE scoring. This summarizes the ASCI-PT 2020 proceedings and provides a consensus statement for conducting semi-quantitative LGE scoring.

Key words Heart · Magnetic resonance image · Late gadolinium enhancement · Consensus · Asian Society of Cardiovascular Imaging-Practical Tutorial.

INTRODUCTION

The evaluation of myocardial viability is one of the most venerable and essential objectives of cardiac magnetic resonance (CMR) [1-4]. Several studies have reported that the degree of myocardial infarction assessed by late gadolinium enhancement (LGE) is associated with left ventricular functional recovery and patient outcomes [1,5,6]. Although the clinical efficacy of myocardial viability evaluation using conventional methods [i.e., single-photon emission CT (SPECT) and stress echocardiography] was questioned by the results of the recent Surgical Treatment for Ischemic Heart Failure (STICH) trial [7], it paradoxically indicated the requirement for more accurate evaluation of viability using CMR or cardiac positron emission tomography [8]. CMR, which is a more accurate tool for evaluating viability than SPECT and stress echocardiography, is expected to garner increased research interest and clinical application [8]. The actual LGE evaluation process with either visual scoring or quantification can be complicated and ambiguous, despite the existence of well-framed guidelines for LGE evaluation [9-12], The chief difficulty entails dividing the left ventricular myocardium into 16 or 17 segments, defining the lesion, and determining the lesion's extent [13].

The Asian Society of Cardiovascular Imaging-Practical Tutorial (ASCI-PT) was founded in 2019 as an educational program of the ASCI School [14]. The ASCI-PT 2019 was conducted successfully with 32 participants from 12 countries [14]. However, conducting the ASCI-PT offline with international attendees was impossible in 2020 owing to the COVID-19 pandemic. The ASCI-PT 2020 was planned to reach a consensus on common and critical issues related to CMR interpretation, and semi-quantitative LGE scoring was chosen as the topic. After confirming that the ASCI-PT 2020 was to be held in Seoul, South Korea, invitations were sent to Korean ASCI members and ASCI executive committee members abroad. The final list of 18 panelists who agreed to participate is presented in Table 1. From the beginning, ASCI-PT 2020 was planned in such a way so as to comply with the social distancing norms established at the time of the COVID-19 pandemic. Therefore, domestic participants from South Korea were instructed to freely engage in both online and offline sessions. Moreover, online rather than offline participation was recommended according to the Korean government's social distancing policy, as the ASCI-PT 2020 was held from November 23rd to 25th, 2020. This study aimed to summarize ASCI-PT 2020 and provide a consensus statement to clarify the possible pitfalls of performing LGE scoring by applying the existing CMR guidelines.

CASES, PARTICIPANTS, AND SCHEDULES

For ASCI-PT 2020, 26 CMR cases with ischemic cardiomyopathy were collected from 13 hospitals in South Korea, which were acquired using eight different MRI machines manufactured by three companies. The details of these 26 cases are presented in Table 2. The images were acquired according to the protocol actually used by each hospital in order to achieve a more practical consensus. Using images acquired with various MRI protocols was deemed more meaningful because each hospital tends to use different patterns in the clinical setting. Therefore, we attempted to collect MRI images obtained with as wide a range of protocols as possible so that our consensus criteria could be applicable to routine clinical interpretation.

Eighteen experts from five countries participated as panelists. According to the pre-meeting survey, 52.9% of participants had more than 10 years of CMR experience after board-certification. For the purpose of viability evaluation, more than 20 CMR examinations were performed in a month at 47.1% of the participants' institutions, and more than 10 CMR examinations were acquired at 23.5% of participants' institutions. Myocardial viability was evaluated using semi-quantitative methods by 70.6% of participants (e.g., 25% transmural extent in segments 1 and 7; >75% extent in segment 5), while 35.3% of participants reported using descriptive methods (e.g., viability in the left anterior descending artery territory, non-viability in the right coronary artery territory), and 17.6% of participants used completely quantitative reporting with dedicated software (e.g., 25% of infarction burden, 10% of peri-infarction burden).

Since the goal of convening the ASCI-PT 2020 was to increase the interobserver agreement for LGE scoring after achieving an expert consensus, all participants were required to score 26 cases posted on the website prior to the ASCI-PT 2020 meeting. LGE scoring was based on the extent of LGE in each of the 17 segments recommended by the American Heart Association as follows: score 0, 0%; score 1, 1−25%; score 2, 26−50%; score 3,

Table 1. List of participants

Name	Nationality	Participation route
1. Jongmin Lee	South Korea	Online
2. Sang Il Choi	South Korea	Offline/online
3. Bae Young Lee	South Korea	Offline/online
4. Whal Lee	South Korea	Offline/online
5. Dong Hyun Yang	South Korea	Offline
6. Sung Mok Kim	South Korea	Offline
7. Young Jin Kim	South Korea	Online
8. Chul Hwan Park	South Korea	Offline
9. Eun-Ju Kang	South Korea	Offline/online
10. Sung Ho Hwang	South Korea	Offline/online
11. Cherry Kim	South Korea	Offline
12. Chan Ho Park	South Korea	Offline
13. Min Jae Cha	South Korea	Offline
14. Hyun Jung Koo	South Korea	Offline/online
15. Sanjaya Viswamitra	India	Online
16. Rungroj Krittayaphong	Thailand	Online
17. Nguyen Ngoc Trang	Vietnam	Online
18. Kakuya Kitagawa	Japan	Online

51−75%; and score 4, 76−100%. All participants scored the extent of LGE according to the method they had been using so far without any special guidance. Seventeen of the 18 participants completed LGE scoring for all segments of 26 cases on the website prior to the consensus meeting.

The detailed schedule of the ASCI-PT 2020 is depicted in Table 3. All online/offline participants re-implemented LGE scoring for 26 cases on the website based on the new consensus, which was created after all the online/offline participants reviewed and approved the consensus. The results of the ASCI experts' final scoring for each case can be accessed from the website (https://www.asci-heart.org:4442/meeting/programPT_2020.php).

ISSUES IN LGE SCORING: REVIEW OF IMAGING GUIDELINES

The interpretation of LGE imaging is a complex and intricate process. Several well-written comprehensive guidelines are available for CMR interpretation [9,10]. According to these guidelines, visual interpretation and semi-quantitative scoring

Table 2. Details of 26 cardiac magnetic resonance cases

Online case number	Age	Sex	Vendor	Machine	Tesla	Comment
Case 01	66	M	Philips	Ingenia CX	3T	MI, RCA/LCX territories
Case 02	47	M	Siemens	Avanto	1.5T	MI, RCA/LCX territories
Case 03	52	M	Siemens	Vida	3T	MI, LAD territory
Case 04	50	F	Siemens	Vida	3T	MI, LAD/LCX territories
Case 05	49	M	GE	Architect	3T	MI, LCX territory
Case 06	58	M	GE	Architect	3T	MI, LAD territory
Case 07	57	M	GE	Discovery750	3T	MI, LAD territory
Case 08	65	M	GE	Discovery750	3T	MI, LAD territory
Case 09	59	M	Siemens	Skyra	3T	MI, RCA territory
Case 10	61	F	Siemens	Skyra	3T	MI, RCA territory
Case 11	72	M	Philips	Ingenia	3T	MI, RCA territories
Case 12	86	M	Philips	Ingenia	3T	MI, LAD/LCX territories
Case 13	71	M	Siemens	Avanto	1.5T	MI, LAD territory
Case 14	60	M	Siemens	Avanto	1.5T	MI, LCX territory
Case 15	57	M	Siemens	Skyra	3T	MI, RCA territory
Case 16	50	M	Siemens	Skyra	3T	MI, RCA/LAD/LCX territories
Case 17	55	M	Siemens	Prisma-fit	3T	MI, RCA territory
Case 18	44	M	Siemens	Prisma-fit	3T	MI, RCA/LAD/LCX territories
Case 19	53	M	Siemens	Skyra	3T	MI, RCA territory
Case 20	48	M	Siemens	Skyra	3T	MI, LAD territory
Case 21	50	M	Siemens	Skyra	3T	MI, LAD territory
Case 22	52	M	Siemens	Skyra	3T	MI, LCX territory
Case 23	35	M	Siemens	Vida	3T	MI, RCA/LAD territories
Case 24	64	M	Siemens	Vida	3T	MI, LAD territory
Case 25	56	F	Siemens	Vida	3T	MI, LAD territory
Case 26	52	M	Siemens	Vida	3T	MI, LAD territory

MI: myocardial infarction, RCA: right coronary artery, LAD: left anterior descending artery, LCX: left circumflex artery

Table 3. Schedule of the ASCI-PT 2020

<table>
<tr><th>Time</th><th>November 23 (Monday)
pre-drafting and case review</th><th>November 24 (Tuesday)
ASCI-PT</th><th>November 25 (Wednesday)
wrap-up</th></tr>
<tr><td>09:00–09:30</td><td>Introduction and motivation
(Dong Hyun Yang)</td><td rowspan="2">Case review and discussion
(offline participants)</td><td rowspan="7">Consensus draft finalization
(offline participants)</td></tr>
<tr><td>09:30–10:00</td><td>Guideline review: LGE scoring
(Chul Hwan Park)</td></tr>
<tr><td>10:00–10:30</td><td>Previous literature review: LGE scoring
(Cherry Kim)</td><td rowspan="2">Consensus draft review and discussion
(offline participants)</td></tr>
<tr><td>10:30–11:00</td><td>Pre-meeting score review and
key questions (Dong Hyun Yang)</td></tr>
<tr><td>11:00–11:30</td><td rowspan="3">Consensus draft review and discussion
(offline participants)</td><td>Break</td></tr>
<tr><td>11:30–12:00</td><td rowspan="3">Online meeting with ASCI experts
- consensus statement review
(all participants)</td></tr>
<tr><td>12:00–12:30</td></tr>
<tr><td>12:30–13:00</td><td rowspan="2">Lunch</td><td rowspan="11"></td></tr>
<tr><td>13:00–13:30</td><td>Break</td></tr>
<tr><td>13:30–14:00</td><td rowspan="3">Consensus draft review and discussion
(offline participants)</td><td rowspan="3">Online meeting with ASCI experts
- confirmation of the semi-quantitative LGE score for CMR cases (all participants)</td></tr>
<tr><td>14:00–14:30</td></tr>
<tr><td>14:30–15:00</td></tr>
<tr><td>15:00–15:30</td><td rowspan="6">Case review and discussion
(offline participants)</td><td rowspan="6">Case review (quantification with CMR 42)
- introduction and demonstration
(offline participants)</td></tr>
<tr><td>15:30–16:00</td></tr>
<tr><td>16:00–16:30</td></tr>
<tr><td>16:30–17:00</td></tr>
<tr><td>17:00–17:30</td></tr>
<tr><td>17:30–18:00</td></tr>
</table>

CMR: cardiac magnetic resonance, LGE: late gadolinium enhancement, ASCI-PT: Asian Society of Cardiovascular Imaging-Practical Tutorial

constitute the various steps including determining the presence of LGE, describing the location of LGE, evaluating the extent of LGE, and semi-quantitative scoring. However, various arbitrary points need further clarifications and consensus. We have carefully reviewed the previous guidelines for LGE interpretation and addressed seven issues to improve communication and reduce inter-observer variability in the interpretation of LGE.

Issues of myocardial segmentation (issues 1–5)

Issue 1. how to define the three slices of left ventricle myocardium as apical, mid, or basal

Currently, left ventricle (LV) evaluation is based on 17 standardized myocardial segments according to a method reported in 2002 [15]. According to this standard LV segmentation nomenclature, the LV is divided into three circular short-axis slices that are ideally equal to the long axis of the heart. However, papillary muscles could be used as intra-cardiac landmarks of the mid-cavity in echocardiography, because it is not feasible to obtain short-axis images that can be cross referenced with long-axis images [15]. Papillary muscles should be used for slice selection to ensure consistency between the respective echocardiography and CMR interpretations. However, CMR could facilitate more accurate equal interval divisions by using the short-axis and long-axis images simultaneously (Table 4). In 2018, Selvadurai et al. [13] recommended that the LV should be divided equally on the LGE images, using long-axis images for more objective and reproducible segmentation.

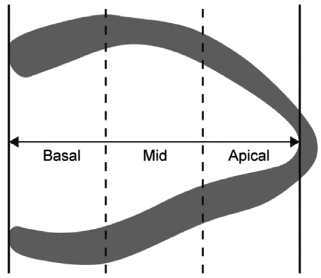
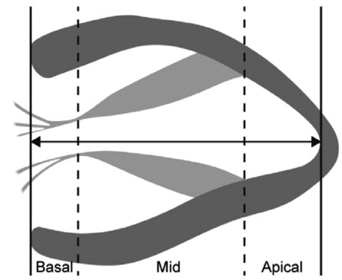
Issue 2. how to define the most basal short-axis image on the basal LV slice

The basal segment of the LV terminates by extending into the mitral annulus, and the LV outflow tract is usually visualized on the basal slices of the LV simultaneously. The standard LV segmentation nomenclature recommends selection of basal slices from the base of the heart, and only slices containing myocardium through all 360° should be selected on echocardiography [15]. However, the basal myocardium, which is displayed with the LV outflow tract on short-axis images, could be regarded as the LV myocardium on CMR, and could provide more accurate information on myocardial mass and infarction (Table 5).

Issue 3. how to define the segment 17

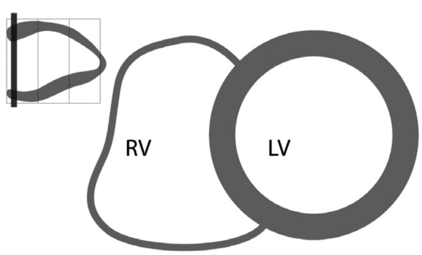
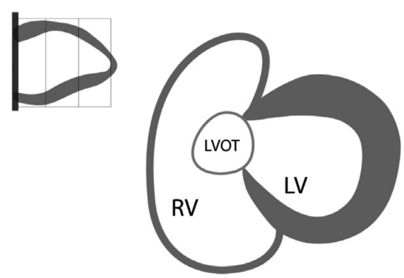
The 17th or apex segment is defined as the area of the myocardium beyond the end of the LV [15]. However, the guideline

Table 4. Issue 1. how to define the 3 slices of LV myocardium as apical, mid, or basal: possible options based on the guidelines

Method	The LV is divided into 3 equal slices	Papillary muscles are used as landmarks of the mid LV
		
Pros	Equal length of apical-mid-basal slices	Does not need longitudinal images; possible with short-axis images alone
Cons	Needs longitudinal images with cross-reference function	Uneven length of apical-mid-basal slices

LV: left ventricle

Table 5. Issue 2. how to define the most basal short-axis image on the basal LV slice: possible options based on the guidelines

Method	Most basal slice: last slice containing myocardium in all 360°	Most basal slice: most basal slice containing myocardium without partial volume artifacts
		
Pros	Selection of the most basal slice is more robust	Can evaluate the whole LV myocardium
Cons	Cannot evaluate part of the LV myocardium	Partial volume artifact could mimic infarction

LV: left ventricle, RV: right ventricle, LVOT: LV outflow tract

provides two different schemes for the apex segment (Table 6).

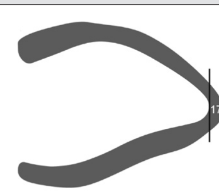
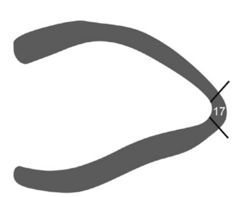
Issue 4. how to define the most apical short-axis image of the apical LV slice

The apical slice includes the distal third of the LV myocardium from its border with the mid-cavity to the end of the left ventricular cavity. The most apical short-axis images could change depending on the definition of the apex (segment 17).

Issue 5. how to define the segments in short-axis images

According to the standard LV segmentation nomenclature, the basal and mid slices are divided into 6 segments and the apical segment is divided into 4 segments, which adds up to 17 segments when counting the apex segment [15]. This original study recommended two principles for slice segmentation. First, the LV septum should be defined using two right ventricle (RV) insertion points. Second, the basal and mid LV should be divided into 6 segments with equal angles of 60°. The apical segment should be divided into 4 segments with equal angles of 90°.

Table 6. Issue 3. how to define the segment 17: possible options based on the guidelines

Method	
	Segment 17: The apex segment shares a perpendicular border with the apical slice, similar to those of the mid and basal slices
	Segment 17: The apex segment is wedge-shaped on the long-axis view

However, these two principles may come into conflict with each other if the septum between the two RV insertion points does not have a central angle of 120° (basal and mid LV) or 90° (apical LV). In contrast, one RV insertion point could be used as a landmark, and slices could be divided into equiangular segments. However, in this case, the LV septum is not defined accurately, which could result in misalignment. Furthermore, it is not clear which RV insertion point should be used as a landmark (Table 7). In 2018, Selvadurai et al. [13] recommended the use of both RV insertion points to define the two major axes as this provides more accurate alignment of the LV septum without equiangular segmentation.

Issue of LGE definition (issue 6)

Issue 6. how to define the presence of LGE

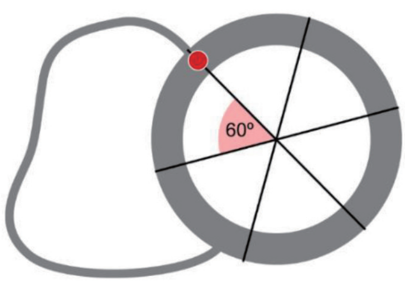
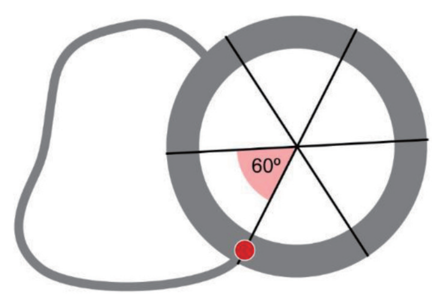
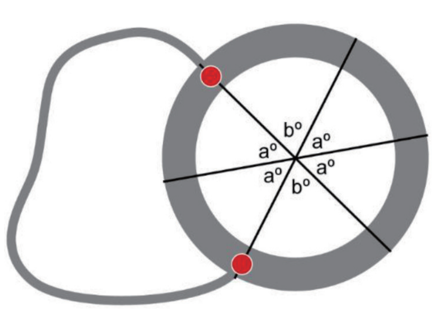
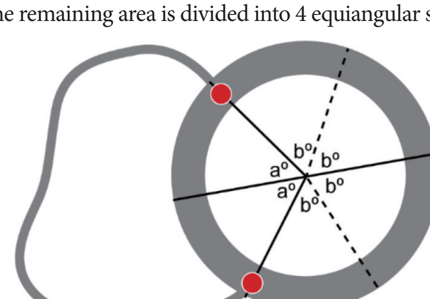
The earlier guidelines recommended that LGE could be determined to be present if the signal intensity of the lesion is as bright as the LV blood pool [12,16]. However, the updated 2020 Society for Cardiovascular Magnetic Resonance guidelines recommend that LGE can be determined to be present if the signal intensity of the lesion is visibly brighter than that of the 'nulled' myocardium [9].

Issue of LGE scoring (issue 7)

Issue 7. how to perform semi-quantitative scoring of LGE

The earlier guidelines recommended a scoring system for LGE using a five-point scale based on the average transmural extent [9,12,16]. However, there are two drawbacks to this statement, both of which deal with semi-quantitative LGE scoring. The first is the meaning of the term "the average transmural extent." The average transmural extent of the infarction (or hyper-enhanced myocardium) can be confused with the transmurality of infarction or transmural extent of infarction. The average transmural extent was originally evaluated as the percentage of the hyper-enhanced area [1,17]. This concept of the average transmural extent of infarction could represent the burden of myocardial infarction in each segment. Historically, Kim et al. [1,17] reported that the average extent of myocardial infarction evaluated by delayed enhancement could predict the recovery of the infarcted myocardium after re-perfusion. Therefore, the aforementioned guidelines recommended a 5-point scoring based on the average transmural extent of infarction, which is

Table 7. Issue 5. how to define the segments in short-axis images: possible options based on the guidelines

Method	Each LV slice is divided into 6 (mid, basal slices) or 4 (apical slice) equiangular segments with the anterior RV insertion points as landmarks	Each LV slice is divided into 6 (mid, basal slices) or 4 (apical slice) equiangular segments with the posterior RV insertion points as landmarks
		
Pros	Equiangular segments	Equiangular segments
Cons	The septum is not defined accurately	The septum is not defined accurately
Method	The septum is defined by using both RV insertion points, which define 2 major axes; the third axis divides the septum equally	The septum is defined using both RV insertion points, which define 2 major axes; the septum is divided equally, and the remaining area is divided into 4 equiangular segments
		
Pros	The septum is defined accurately	The septum is defined accurately
Cons	Non equiangular segments	Non equiangular segments

RV: right ventricle, LV: left ventricle

not based on transmurality or the transmural extent of infarction [9,12,16]. In contrast, transmurality entails a one-dimensional (1D) approach that represents the severity of the transmural propagation of infarction, according to the wave-front phenomenon of infarction [18]. The terminology used to refer to the transmural extent of infarction tends to include transmurality (1D concept) rather than average transmural extent of infarction [two-dimensional (2D concept)]; however, the meaning of "transmural extent of infarction" seems to be used ambiguously [18-20].

Second, the 5-point scoring system was initially developed based on analysis of each slice in the LGE image, which was a true 2D approach. Initially, the LV was divided into 72 segments (6 slices; 12 segments per slice), and each segment consisted of only one slice of the LGE image. Therefore, this planimetric estimation of the hyper-enhanced myocardium is wholly 2D, and visual estimation seems to be feasible (Table 8). However, in the standardized 17-segment era, the LV should be divided into 17 segments from 3 slices. CMR usually provides 8−10 slices for the whole LV, so each apical-mid-basal slice of the LV consists of 2 or 3 slices of LGE images. In this situation, each segment should be evaluated by 2 or 3 image slices, and the planimetric estimation (LGE myocardium/whole myocardium) of infarction in each segment is accompanied by 3-dimensional issues, which cannot be easily assessed visually (Table 9).

On the contrary, transmurality or the transmural extent of infarction can be evaluated more easily through visual assessment, compared to average extent of infarction. However, in the 17-segment era, using a scoring system with a non-averaged 1D concept of transmurality or transmural extent of infarction is accompanied by the risk of overestimating localized infarction and creating a less representative nature of the infarct burden.

During the ASCI-PT 2020, participants attempted to arrive at an expert consensus on these 7 practical issues to clarify the arbitrary points of LGE interpretation, based on the previous

Table 8. Original concepts of the average transmural extent of hyper-enhanced myocardium

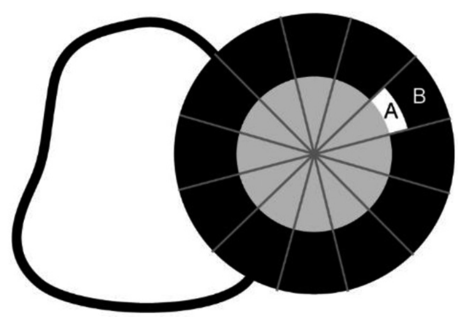
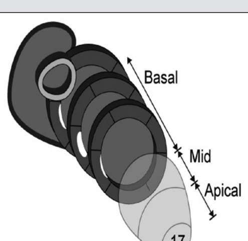
Terminology	Average transmural extent of infarction
Definition	Percentage of hyper-enhanced area =100×hyper-enhanced area÷(hyper-enhanced area+non-enhanced area) in each segment  (Seventy-two segments: 6 slices, 12 segments per slice) (A: hyper-enhanced area, B: non-enhanced area)
Semi-quantitative scoring (grading on the 5-point scale)	Score of 0: no hyperenhancement Score of 1: hyperenhancement of 1 to 25 percent of the tissue in each segment Score of 2: hyperenhancement of 26 to 50 percent of tissue Score of 3: hyperenhancement of 51 to 75 percent of tissue Score of 4: hyperenhancement of 76 to 100 percent of tissue

Table 9. Application of the average transmural extent of infarction to 17 standardized LV segments

Method	
	In this representative LGE image, the basal slice of the LV consists of 3 slices of LGE short-axis images. Segment 3-the inferoseptal segment shows localized subendocardial LGE. The average transmural extent of myocardial hyper-enhancement should be estimated as 100×(sum of the LGE area in segment 3/whole myocardial area in segment 3). This estimation is a 3-dimensional volumetric approach of 100×(volume of LGE in segment 3/whole myocardial volume in segment 3), considering the slice thickness of each LGE image.

LV: left ventricle, LGE: late gadolinium enhancement guidelines and their experience.

CONSENSUS STATEMENT FROM THE ASCI-PT 2020 FOR LGE SCORING

All panels participated in an online or offline session to achieve consensus for LGE scoring. Before participating in the consensus session, LGE scoring was performed individually through a web-based system, and then again after obtaining the consensus. All cases used in the ASCI-PT 2020 can be viewed on the web page (https://www.asci-heart.org:4442/meeting/programPT_2020.php). A reader of this article can perform LGE scoring on their own and compare their results with the panelists' most frequent score. The consensus statement achieved by the panelists of the ASCI-PT 2020 is as follows.

Definition of the apical, mid, and basal slices of the LV myocardium

The LV is divided into 3 equal slices along the long axis of the heart: apical, mid, and basal (Fig. 1).

The papillary muscle can be used as an anatomical landmark for the mid-cavity if the short-axis images do not include the entire volume of the LV or there is no long-axis image for reference.

The most basal short-axis image of the LV basal slice

An image slice containing myocardium in all degrees, except for the left ventricular outflow tract, should be selected (Fig. 2).

Definition of segment 17

Segment 17 is defined as the LV apex containing only myocardium, and not the LV chamber. The apical slice (segments 13, 14, 15, and 16) and segment 17 should be divided by planes parallel to the short-axis slice image (Fig. 3).

The most apical short-axis image of the LV apical slice

The most apical image slice containing the LV chamber in all 360° should be selected (Fig. 4).

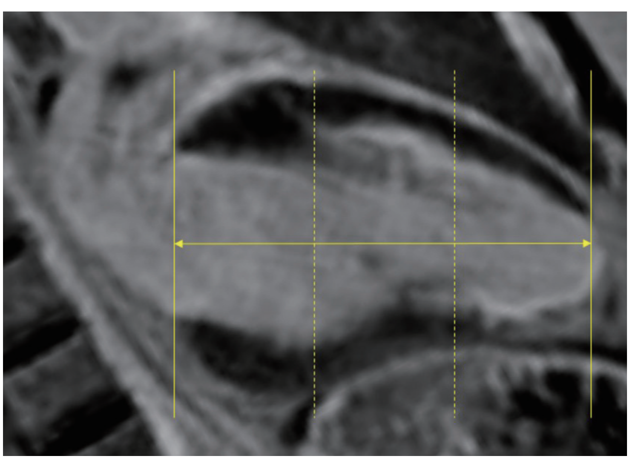


Fig. 1. Asian Society of Cardiovascular Imaging-Practical Tutorial consensus on the definition of the apical, mid, and basal slices of the left ventricle myocardium.

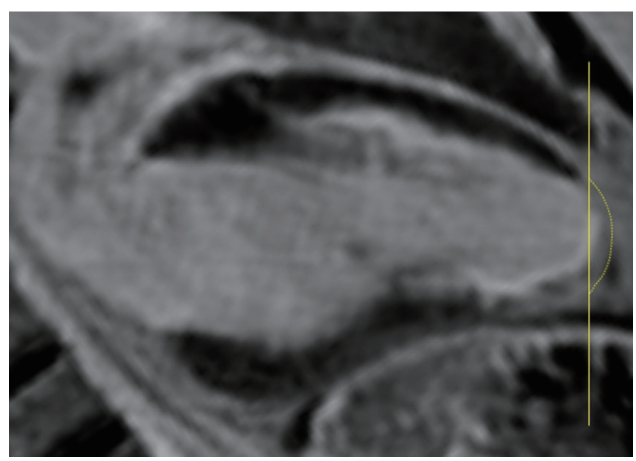


Fig. 3. Asian Society of Cardiovascular Imaging-Practical Tutorial consensus on the definition of segment 17.

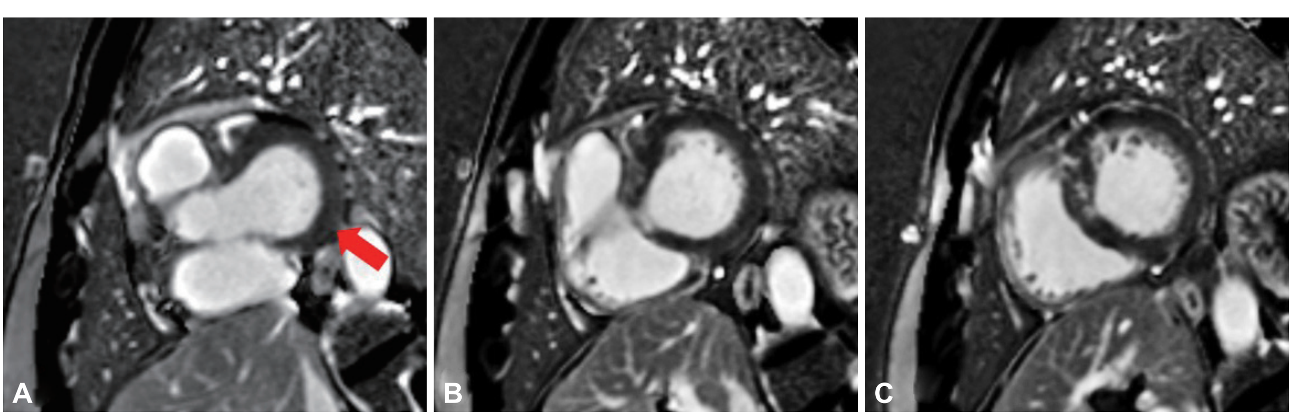


Fig. 2. Asian Society of Cardiovascular Imaging-Practical Tutorial consensus on the most basal short-axis image of the LV basal slice. Among these 3 short axis images (A, B, and C), (A) is recommended as the most basal short-axis image of the LV basal slice (arrow). LV: left ventricle.

Definition of segments on short-axis images

Both anterior and posterior RV insertion points should be used to define the interventricular septum and two major axes. For the basal and mid slices, the septal and lateral walls are further divided using equal angles. Therefore, the angles of each myocardial segment cannot be equal (Fig. 5).

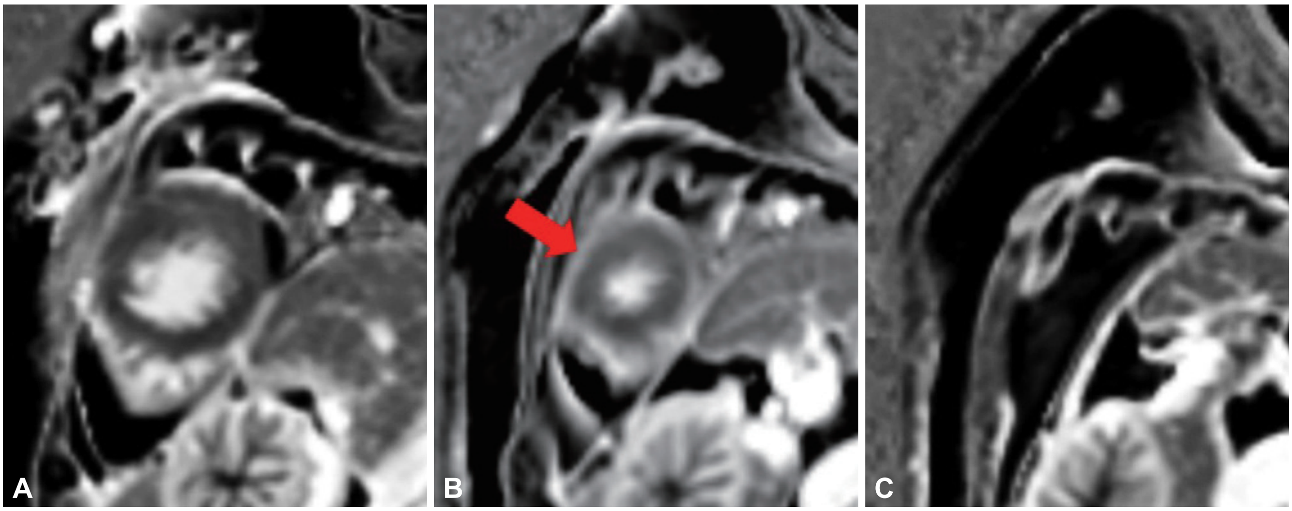


Fig. 4. Asian Society of Cardiovascular Imaging-Practical Tutorial consensus on the most apical short-axis image of the LV apical slice. Among these 3 images (A, B, and C), (B) is recommended as the most apical short-axis image of the LV apical slice (arrow). LV: left ventricle.

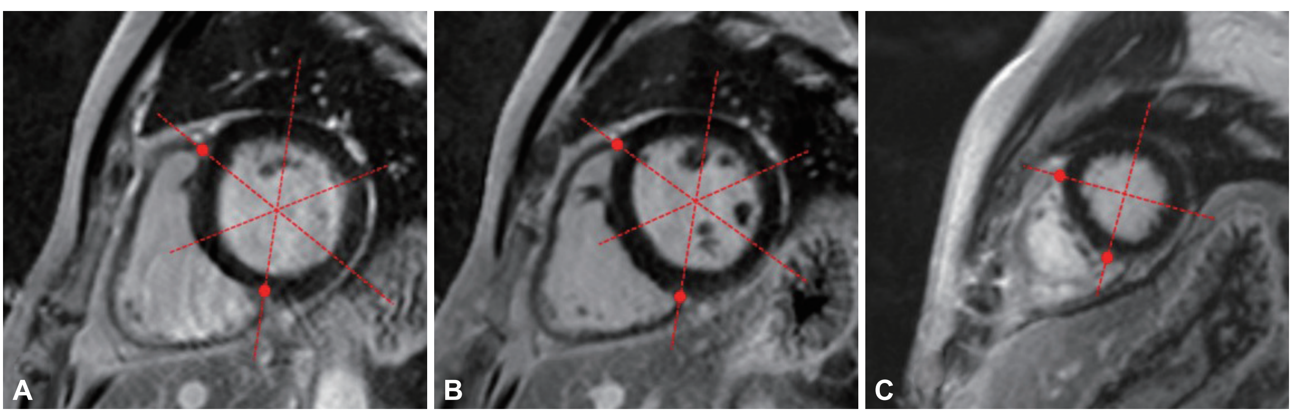


Fig. 5. Asian Society of Cardiovascular Imaging-Practical Tutorial consensus on the definition of segments on short-axis images. A: Segments 1–6. B: Segments 7–12. C: Segments 13–16.

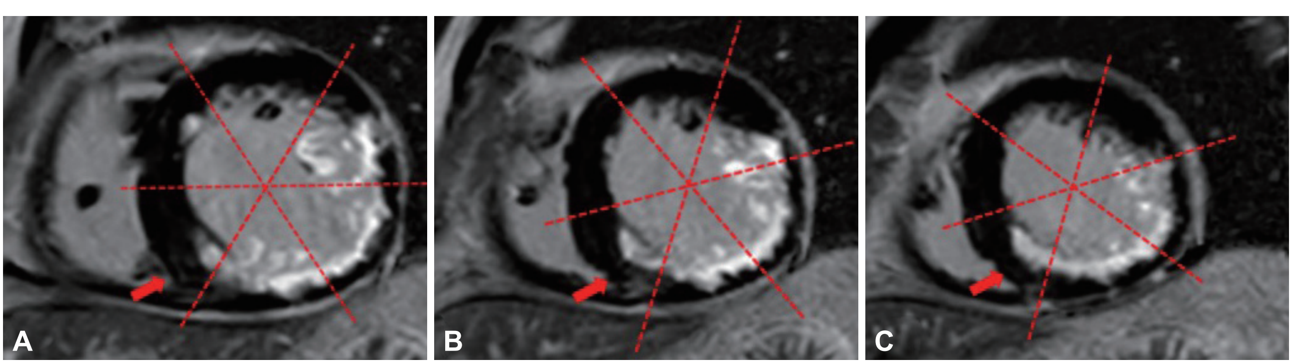


Fig. 6. Asian Society of Cardiovascular Imaging-Practical Tutorial consensus on the semi-quantitative scoring of LGE. The mid-LV consists of 3 slices of LGE short-axis images (A, B, and C) of a 66-year-old man with myocardial infarction. The average transmural extent of the hyper-enhanced myocardium should be estimated as 100×(sum of the LGE area in each segment/whole myocardial area in each segment) using these 3 slices of the LGE short-axis image. For example, segment 9—the inferoseptal segment of the mid-LV—depicts localized subendocardial LGE (arrows) near segment 10. The transmurality of hyper enhanced-myocardium in segment 9 seems to be approximately 50%. However, the average transmural extent of the hyper-enhanced myocardium is less than 25%, and the semi-quantitative score of hyper-enhanced myocardium in segment 9 was 1 after consensus. LV: left ventricle, LGE: late gadolinium enhancement.

Definition of the delayed enhancing lesion

The delayed enhancing lesion is defined as an area that is visibly brighter compared to the 'nulled' myocardium in ischemic cardiomyopathy.

Definition of delayed enhancing lesion extent in a myocardial segment (scoring)

The extent of LGE in a myocardial segment can be estimated as the planimetric extent of the lesion within each segment using a five-point scale (score 0, 0%; score 1, 1−25%; score 2, 26−50%; score 3, 51−75%; score 4, 76−100%).

It is noteworthy that the planimetric extent in this scoring system differs from the 'maximum transmurality' concept, which might reflect the transmural severity of myocardial infarction.

If a segment consists of multiple short-axial slices, the average transmural extent can be estimated using the three-dimensional volumetric concept (i.e., sum of LGE area in each slice/whole segmental myocardial volume) (Fig. 6).

LIMITATIONS AND PERSPECTIVES

The following points should be accounted for while applying this consensus statement. First, this consensus intended to apply the previously published guidelines [9,10,15,16] to actual LGE analysis, especially for semi-quantitative scoring. Although the consensus was drawn through a serious and careful discussion among imaging experts from the ASCI-PT panel, some decisions have no concrete scientific evidence based on experimental or prognostic studies. Second, a "CMR consumer" (e.g., a cardiologist with echocardiography as a subspecialty or a cardiac surgeon) was not included in the consensus panel. This consensus may differ from these specialists' concept of myocardial segmentation; hence, caution must be exercised while applying this consensus to generate CMR reports or research results. However, this consensus statement may be helpful in preventing misunderstanding when communicating with the CMR consumer. Third, due to the COVID-19 pandemic, all offline readers were Koreans, which could have been a cause of bias. Forth, this consensus document was developed for the semi-quantitative analysis of conventional LGE images in patients with ischemic cardiomyopathy. Special conditions such as aneurysmal dilatation or non-ischemic cardiomyopathy could hamper the application of this consensus document. Despite these limitations, we believe that this statement will improve the interpretation consistency of CMR among clinicians.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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ORCID iDs

Chul Hwan Park	https://orcid.org/0000-0002-0004-9475
Cherry Kim	https://orcid.org/0000-0002-3361-5496
Bae Young Lee	https://orcid.org/0000-0002-3426-9660
Chan Ho Park	https://orcid.org/0000-0002-0653-4666
Eun-Ju Kang	https://orcid.org/0000-0003-0937-3607
Hyun Jung Koo	https://orcid.org/0000-0001-5640-3835
Kakuya Kitagawa	https://orcid.org/0000-0003-4402-6846
Min Jae Cha	https://orcid.org/0000-0001-6358-8081
Rungroj Krittayaphong	https://orcid.org/0000-0001-8684-2361
Sang Il Choi	https://orcid.org/0000-0002-1323-2279
Sanjaya Viswamitra	https://orcid.org/0000-0002-0913-7578
Sung Min Ko	https://orcid.org/0000-0002-7420-6269
Sung Mok Kim	https://orcid.org/0000-0001-5190-2328
Sung Ho Hwang	https://orcid.org/0000-0003-1850-0751
Nguyen Ngoc Trang	https://orcid.org/0000-0002-5965-5381
Whal Lee	https://orcid.org/0000-0003-1285-5033
Young Jin Kim	https://orcid.org/0000-0002-6235-6550
Jongmin Lee	https://orcid.org/0000-0002-4163-913X
Dong Hyun Yang	https://orcid.org/0000-0001-5477-558X

Author Contributions

Conceptualization: Jongmin Lee, Dong Hyun Yang. Data curation: all authors. Formal analysis: all authors. Funding acquisition: Jongmin Lee, Dong Hyun Yang. Investigation: all authors. Methodology: Dong Hyun Yang, Chul Hwan Park, Cherry Kim. Project administration: Dong Hyun Yang. Resources: Jongmin Lee, Dong Hyun Yang. Software: Dong Hyun Yang, Chul Hwan Park, Cherry Kim. Supervision: Jongmin Lee, Kakuya Kitagawa, Rungroj Krittayaphong, Sanjaya Viswamitra, Nguyen Ngoc Trang. Validation: all authors. Visualization: all authors. Writing—original draft: Dong Hyun Yang, Chul Hwan Park, Cherry Kim. Writing—review & editing: all authors.

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