A summary of the 2014 FGI and sound & vibration guidelines for healthcare facilities

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ABSTRACT

The FGI *Guidelines* are the two-volume standard reference document for healthcare construction. Both volumes (hospitals; residential care) include comprehensive acoustical criteria written in code language that are used by authorities in the United States and 60 other countries, and serve as the sole reference for acoustics in USGBC-LEED for Health Care. The acoustical criteria set "minimum standards" and were developed by the FGI Acoustics Working Group, a ten-year-old standing committee including members of the Acoustical Society of America, INCE-USA, and other professional organizations. This group authors the sole acoustical reference for the Guidelines called *Sound & Vibration Design Guidelines for Health Care Facilities* (S&V-3.0-2014), publically available on the FGI website and to be published by Springer-Verlag during the first half of 2015. The *Guidelines* are edited and re-issued every four years by the Facility Guidelines Institute, and jointly published with the American Hospital Association. The *Guidelines* are revised following an open, formal, Continual Improvement Process that includes a peer- and public-review incorporating the latest research and changes in healthcare laws. This discussion by the national Secretary of the FGI Acoustics Working Group and the Chair of its Education Committee will: address the new code requirements related to acoustics; summarize the myriad changes from the 2010 edition; and describe the public and comment process for the next edition to be released in 2018.

Keywords: Healthcare, Noise Control I-INCE Classification of Subjects Number: 51.1.5

1. INTRODUCTION

1.1 FGI Guidelines

The *Guidelines* originally began in 1947 as the *General Standards*, which documented federally regulated “minimum standard” building codes for healthcare facilities in the United States. Although no longer regulated by U.S. law, the *Guidelines* continue to provide recommendations written in terms of “minimum standards” that cover many aspects of healthcare design. Today, the continual production, maintenance and improvement of the Guidelines is tasked to the Facility Guidelines Institute (FGI), a non-profit corporation originally formed in 1998 (1).

New to the 2014 revision cycle, this once-singular document has been split into two volumes: *Guidelines for Design and Construction of Hospitals and Outpatient Facilities* and *Guidelines for Design and Construction of Residential Health, Care, and Support Facilities*. The former closely resembles previous versions of the *Guidelines* while the latter was written in recognition of the need for residential care areas, whose goal is to provide care while fostering a home-like environment, to be treated separately. This volume covers facilities such as nursing homes, hospices, assisted living facilities, independent living settings, adult day care facilities, wellness centers, and outpatient rehabilitation centers (2).

The *Guidelines* are edited and re-issued every four years following an open, formal, Continual

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Improvement Process that includes a peer- and public-review incorporating the latest research and changes in healthcare laws. This work is done by the FGI's Health Guidelines Revision Committee (HGRC), which is composed of a multi-disciplinary group of experts related to healthcare facilities (1).

Comprehensive acoustical criteria for healthcare facilities were formally introduced into the *Guidelines* beginning in the 2010 cycle. This was in response to such issues as patient privacy – protected under United States law by the Health Insurance Portability and Accountability Act (HIPAA) (3) – and evidence of the detrimental effects of poor hospital acoustics on both patients and staff (4-10). The acoustical criteria are developed by the FGI Acoustics Working Group, a ten-year old standing committee including members of the Acoustical Society of America, INCE-USA, and other professional organizations. This group authors the *Sound & Vibration Design Guidelines for Health Care Facilities* which serves as the sole acoustical reference for the *Guidelines*.

The influence of the *Guidelines* is far-reaching: Although adoption of the *Guidelines* varies by state, forty-two states use the *Guidelines* in some form and they have been utilized in 60 countries (11) (see Figures 1 and 2 below).

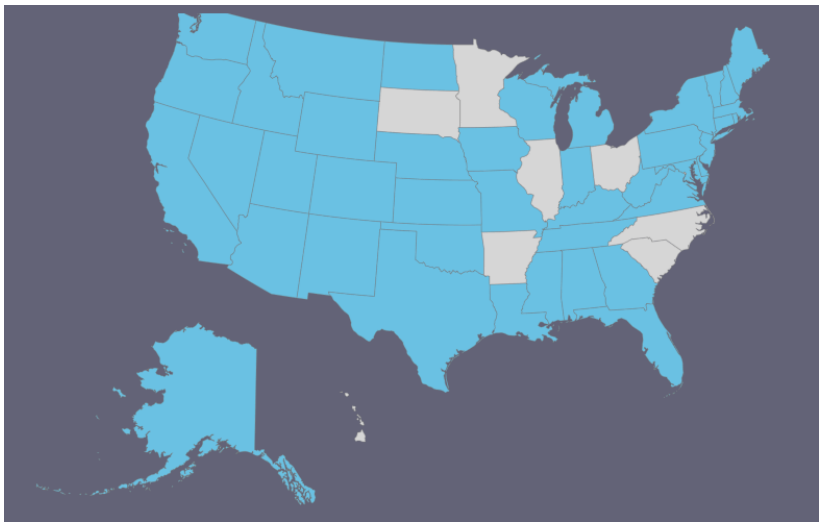

Figure 1 – States where the FGI Guidelines are used as building code – United States (12)
(*maps adapted from amCharts.com*)

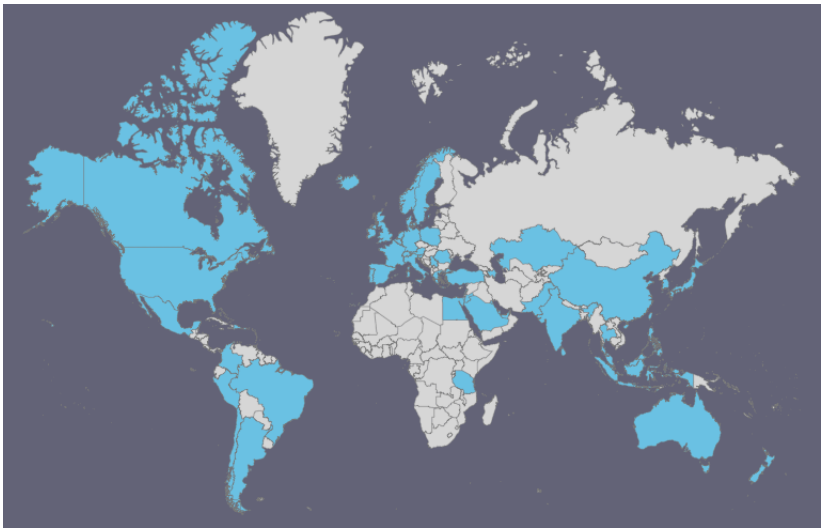

Figure 2 – Countries where the FGI *Guidelines* have been used as a reference – International (12)
(*maps adapted from amCharts.com*)

1.2 Other International Healthcare Acoustics References

The FGI *Guidelines* are only one of several healthcare documents containing specific acoustical criteria. Some of the most well-known documents are summarized by Clarke (13):

1.2.1 Health Technical Memorandum HTM 08-01: Acoustics

This document is used in the United Kingdom. Its intention is to both inform healthcare professionals of acoustical requirements in hospitals and also to help professionals involved in the development of healthcare facilities. It provides acoustic criteria for new healthcare facilities but does not provide design recommendations on how to achieve those criteria. The acoustical criteria include, but are not limited to: levels of noise intrusion from external sources, noise produced by building systems, sound-insulating partition ratings (dB $D_{nT,w}$), acoustical treatments, and vibration (13, 14).

1.2.2 AS/NZ 2107:2000 Acoustics – Recommended design sound levels and reverberation times for building interiors (AS2107) and Australian Health Facility Guidelines Revision v4.0 (AusHFG)

AS2017 provides recommendations for acoustical design in healthcare facilities in terms of recommended sound levels and reverberation time. The background noise levels are provided in terms of 'satisfactory' and 'maximum' recommended design levels, which are similar to the recommended background noise levels by HTM 08-01 and the *Guidelines* (13, 15).

AusHFG defines the base requirements for healthcare facilities in the design and construction of healthcare facilities. Acoustics are referred to in terms of general definitions and guidelines in parts B and C. Sound isolation is described only qualitatively without reference to specific acoustical criteria. Some criteria for reverberation time, background noise levels, and vibration are included, which reference Australian Standards AS2017 and AS2670.1 (Evaluation of human exposure to whole-body vibration) (13, 16).

1.2.3 CSA Z8000-11 Canadian Healthcare Facilities

CSA Z8000-11 provides general guidance regarding several aspects of acoustical design as well as specific design criteria for sound isolation (STC), background noise levels (NC) and minimum performance for acoustical ceilings in some spaces (NRC). Background noise requirements reference CAN/CSA-Z317.2 (*Special requirements for heating, ventilation, and air-conditioning (HVAC) systems in health care facilities*). Other conditions that must be met include a requirement that an acoustic study "shall be completed in all MRI suite designs" as well as defined limits on footfall floor vibration in operating rooms and sensitive inpatient bedrooms (17).

2. 2014 FGI GUIDELINES ACOUSTICAL CRITERIA (18, 19)

2.1 Introduction

Acoustical design criteria for healthcare facilities are provided within the "Planning and Design Considerations and Requirements" section of Part 1 of the *Guidelines for Design and Construction of Outpatient Facilities* and the "Building Systems" section of Part 2 of the *Guidelines for Design and Construction of Residential Health, Care, and Support Facilities*. For both volumes (hereafter generally referred to as FGI 2014), the acoustical criteria are organized into the following categories: site exterior noise, acoustic finishes, room noise levels, sound isolation, speech privacy, and building vibration.

2.2 Site Exterior Noise

FGI 2014 requires that the sound isolation provided by the exterior shell (including the exterior wall/window assemblies, penetrations, etc.) of healthcare facilities be designed to result in appropriate interior noise levels. Both exterior noise transmitted into the building and noise produced by the facility reaching nearby receptors (neighbors) is to be considered.

This section classifies exterior site noise into one of four categories and provides prescriptive building envelope Outdoor-Indoor Transmission Class (OITC) (20) ratings determined by the site exposure, as shown below in Table 1 (a more complete version of this table is presented in Table 1.2-3 of *Guidelines for Design and Construction of Outpatient Facilities* and Table 2.5-3 of *Guidelines for Design and Construction of Residential Health, Care, and Support Facilities*). The site noise exposure categories are determined by evaluating the day-night average sound level (Ldn, dB) and the average hourly maximum sound level (L01, dBA).

Relaxed requirements (up to 10 dB) for interior spaces that are less sensitive to noise (such as stairways or corridors) are permitted. Conversely, spaces that are more sensitive to noise (such as a teleconferencing space or auditorium) require special consideration. A separate, non-prescriptive, resource is also given to approximate the site noise exposure by the distance to nearby transportation noise sources.

Table 1: FGI 2014 exterior site noise exposure categories (18, 19)

Exterior Site Noise Exposure Category	General Description	Exterior Shell Composite OITC Rating ($OITC_C$)
A	Minimal	25
B	Moderate	30
C	Significant	35
D	Extreme	40

2.3 Acoustic Surfaces

In order to foster a pleasing acoustical environment for patients/residents and staff, FGI 2014 sets minimum average room absorption coefficients – rather than specifying specific acoustical finishes to be used – for multiple types of spaces based on their use, which are shown below in Table 2.

The average room absorption coefficient is calculated as the sum of all boundary areas in the room first multiplied by the sound absorbing performance of each material in the room and divided by the sum of the boundary areas, as shown in Equation 1 below:

$$\bar{\alpha}_{design} = \frac{S_1\alpha_1 + S_2\alpha_2 + \ldots + S_n\alpha_n}{S_1 + S_2 + \ldots + S_n} \quad (1)$$

Where S1, S2, … , Sn, are the areas of the room finish materials and α1, α2, … , αn, are the noise reduction coefficients (NRC) of the finish materials (21). Any material used must also satisfy all infection control/cleaning requirements as defined by the facility.

Since the 2010 cycle, the *Guidelines for Design and Construction of Hospitals and Outpatient Facilities* have added Medication Safety Zones and Operating Rooms to the spaces requiring consideration (22). Medication Safety Zones are spaces defined as a "critical area where medications are prescribed, ordered are entered into a computer or transcribed onto paper documents, or medications are prepared or administered" (23) and the addition of these spaces are in response to evidence showing that noise in these spaces affects the rate of medication errors. Similarly, *suggested* (not required) acoustical absorption criteria for Operating Rooms are now provided in order to mitigate factors which can complicate speech communication and endanger medical staffs' concentration at a time when they need it the most.

Many of the spaces of consideration in *Guidelines for Design and Construction of Residential Health, Care, and Support Facilities Guidelines* are the residential-focused counterparts to the spaces in the *Guidelines for Design and Construction of Hospitals and Outpatient Facilities* – such as resident rooms, corridors, and medication rooms. A space unique to the residential version is the Quiet Room which is a single resident room provided "to accommodate care requirements for residents experiencing personal conflicts, agitation, episodic mental disturbances, or similar conditions that require a quiet or low-stimulation, positive distraction room (19)." Where criteria for Quiet Rooms are provided, the same recommendations apply to private speech and hearing services rooms and music therapy rooms.

New to FGI 2014, the mitigation of alarm fatigue is discussed in the appendix section of both volumes. Alarm fatigue is the desensitization to constant monitoring equipment alarms and can lead to dangerous behavior by staff and can cause loss of sleep and an increase in anxiety in patients. Proper levels of absorption in enclosed spaces can reduce the potential for alarm fatigue.

Table 2: Selected FGI 2014 design room sound absorption coefficients (18, 19)

Hospitals and Outpatient Facilities		Residential Health, Care, and Support Facilities	
Space	Design Coefficient	Space	Design Coefficient
Private patient	0.15	Multi-bed/multi-occupancy resident room	0.20
Multi-bed patient	0.15	Corridor (public corridor in resident care areas)	0.20
Corridor	0.15	Medication rooms	0.20
Medication safety zone	0.15	Multiple occupant resident care and activity areas	0.20
Waiting area	0.25	Quiet Room	0.20
Atrium	0.10	Office	0.15
Physician's office	0.15	Examination Room	0.15
Treatment room	0.15		
Operating room	0.10 – *suggested*		

2.4 Room Noise Levels

Noise from building mechanical systems is an important aspect of the acoustical environment and contributes to the overall comfort of both patients and facility staff. FGI 2014 presents maximum criteria for noise in interior occupied spaces in terms of NC, RC (Neutral), RNC, and dBA, some of which are shown below in Tables 3 and 4. New to FGI 2014 is clarification that the criteria outlined in Table 3 refer only to building mechanical system noise in unoccupied rooms rather than overall interior noise levels due to occupant and/or medical equipment noise or noise from external environmental sources.

Rather than providing minimum-maximum criteria as in FGI 2010, FGI 2014 only defines the maximum criteria. In addition to the inclusion of the Medication Safety Zone and Operating Room spaces as described in the previous section, since FGI 2010, FGI 2014 for Outpatient Facilities splits NICU criteria from a single category into "NICU staff and family areas" (with the same maximum noise criteria as FGI 2010) and "NICU sleep areas" (with a maximum level of NC/RC(N)/RNC 30) and the "Doctor's offices, exam rooms" category has been re-labeled into the more general, "Private offices, exam rooms" where the maximum level has raised from NC/RC(N)/RNC 45 to NC/RC(N)/RNC 50 due to current technological limits in ventilation system design.

Table 3: Maximum design criteria for noise levels in interior spaces caused by building systems - Hospitals and Outpatient Facilities (18)

Space	NC / RC(N) / RNC	dBA
Patient rooms	40	45
Medication safety zones	40	45
Multiple occupant patient care areas	45	50
NICU sleep areas	30	35
NICU staff and family areas	35	40
Operating rooms	50	55
Corridors and public spaces	45	50
Private offices, exam rooms	40	45
Conference rooms	35	40
Teleconferencing rooms	25	30
Auditoriums, large lecture rooms	30	35

Table 4: Maximum design criteria for noise levels in interior spaces caused by building systems - Residential Health, Care, and Support Facilities (19)

Space	NC / RC(N) / RNC	dBA
Resident rooms/dwelling units	40	45
Medication rooms	45	40
Multiple occupant resident care areas	45	50
Corridors and community spaces	45	50
Offices, examination rooms	40	45
Conference rooms	35	40
Quiet room	30	35
Community meeting rooms and auditoria	30	35

2.5 Performance of Interior Wall and Floor/Ceiling Constructions

Interior wall and floor/ceiling constructions must provide adequate sound isolation for patient and staff comfort as well as to meet patient privacy requirements. FGI 2014 sets forth minimum required composite sound transmission class (STC_C) performance based upon the function of adjacent spaces—some of which are shown below in Tables 5 and 6.

Since the 2010 cycle, FGI 2014 for Outpatient Facilities states that the composite sound transmission class (STC_C) required for patient, consultation and exam rooms adjacent to a corridor (including the door) is STC_C 35, excluding the door (meaning the performance objective is now assigned to the partition itself), rather than being STC_C 35 with a closed door. It further states that doors are not required to be sound sealed and the use of higher performing doors, full-perimeter gasketing, and bottom seals will be left to the discretion of the facility. These changes were made in response to concerns that the composite rating including doors had required door hardware that may not be compatible with infection control and cleaning requirements. These same qualifications are also included in FGI 2014 for Residential Facilities for resident, examination, and consultation rooms adjacent to corridors.

In addition, both volumes of FGI 2014 clarify that suitable wall assemblies can be selected with +/- 2 STC points from the published minimum values based on its published or tested data. This accounts for variability due to testing method accuracy and repeatability.

Table 5: Selected FGI 2014 minimum sound isolation performance between enclosed rooms (STC_C) - Hospitals and Outpatient Facilities (18)

Adjacency Combination		STC_C
Patient room	Patient room (wall-same floor)	45
Patient room	Patient room (floor-to-floor)	50
Patient room or Exam room	Corridor (with entrance)	35
Patient room or Exam room	Public space	50
NICU	Corridor	50
Toilet Room	Public space	45
Public space	MRI room	50

Table 6: Selected FGI 2014 minimum sound isolation performance between enclosed rooms (STC_C) - Residential Health, Care, and Support Facilities (19)

Adjacency Combination		STC_C
Resident room/dwelling unit	Resident room/dwelling unit	45
Resident room/dwelling unit	Community space	50
Resident room/dwelling unit	Service area	60
Examination room	Corridor (with entrance)	35
Examination room	Multiple-occupant resident care and activity areas or public corridor	50
Toilet room	Multiple-occupant resident care and activity areas or public corridor	45
Consultation room	Multiple-occupant resident care and activity areas or public corridor	50
Consultation room	Resident room/dwelling unit	50
Consultation room	Corridor (with entrance)	35

2.6 Speech Privacy

As previously noted, United States federal law requires medical facilities to safeguard patients' private information. To achieve proper speech privacy and allow some flexibility in the design, FGI 2014 requires that spaces be designed to meet goals using one of four speech privacy metrics—as shown below in Table 7—rather than specifying specific design criteria. The four speech privacy rating methods used by the 2014 Guidelines are PI, AI, SII and SPC. Since FGI 2010, use of the speech transmission index (STI) has been replaced by the speech privacy class (SPC) (24) due to the nature of the metric: STI was created for the assessment of intelligibility of public address and other sound reinforcement systems whereas SPC was developed specifically for evaluating the degree of confidentially provided by a partition.

In addition to the inclusion of SPC, since FGI 2010, the acoustical criteria table showing speech privacy goals (which is the same in both volumes of FGI 2014) has changed significantly: The order of speech privacy goals has been reordered, speech privacy values are now listed as a range, speech privacy values to meet "Secure" speech privacy in enclosed rooms and "Marginal" speech privacy in open-plan spaces have been quantified, and finally, the referenced ASTM/ANSI standard for each speech privacy metric has been added.

Table 7: FGI 2014 design criteria for speech privacy for enclosed rooms and open-plan spaces (18, 19)

Level	Metrics			
Speech Privacy-Closed Plan	PI	AI	SII	SPC
Secure	N/A	N/A	N/A	≥70
Confidential	≥95%	≤0.05	≤0.05	60-69
Normal	80-94%	0.06-0.20	0.11-0.25	52-59
Defining standard	ASTM E1130	ASTM E1130	ANSI S3.5	ASTM E2638
Speech Privacy-Open Plan	PI	AI	SII	SPC
Confidential		Special Consideration Required		
Normal	80-94%	0.06-0.20	0.11-0.25	52-59
Marginal	60-79%	0.21-0.40	0.26-0.45	45-51
Defining standard	ASTM E1130	ASTM E1130	ANSI S3.5	ASTM E2638

2.7 Building Vibration

2.7.1 Mechanical, Electrical and Plumbing Equipment Vibration

Most building mechanical equipment generates vibrations that can be transmitted to the building structure. To avoid structure-borne transmitted sound, and to minimize impact on human comfort or sensitive equipment, all rotating and vibrating components of the building systems should be isolated as recommended in the most current Applications Handbook by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) (25).

2.7.2 Structural Vibration

Vibrations can occur from footfalls, and the velocity of these vibrations will depend upon the building structure (as well as the walker's weight, pace, etc. which are standardized in various evaluation methods). Therefore, the building structure must be designed so as to avoid footfall vibration levels in excess of the values shown below in Tables 8 and 9. In addition, hospitals and healthcare facilities are likely to have sensitive equipment which requires vibration to be sufficiently limited to ensure proper functioning. For such equipment to function as expected, the building must be designed so that vibrations do not exceed the limits recommended by the equipment supplier.

Since the 2010 cycle, FGI 2014 for Outpatient Facilities, the maximum limit on footfall vibration for these areas in FGI 2014 has been increased to 4,000 μin/s to 6,000 μin/s. This was in acknowledgement that the previous peak velocity limit in patient areas was generally too stringent and may have required floor structures that are difficult to implement.

Table 8: Maximum limits on footfall floor vibration - Hospitals and Outpatient Facilities (18)

Space	Footfall Floor Vibration Peak Velocity (μin/s)
Patient rooms and other patient areas	6000
Operating and other treatment rooms	4000
Administrative areas	8000
Public circulation	8000

Table 9: Maximum limits on footfall floor vibration - Residential Health, Care, and Support Facilities (19)

Space	Footfall Floor Vibration Peak Velocity (μin/s)
Resident rooms, dwelling units, and other resident areas	6000
Examination rooms	6000
Administrative areas	8000
Community circulation areas	8000
Quiet room	6000

2.7.3 Structure-borne sound

Both volumes of FGI 2014 require that structurally transmitted sound may not exceed the airborne room noise levels stated in the section, "Room Noise Levels" and also require vibration isolators to be used on sources of structurally borne sound when necessary.

3. PUBLIC REVIEW AND COMMENT PROCESS

The *Guidelines* are revised every four years following a continual improvement process – the Guidelines revision cycle – where material is beta-tested. Revisions and updates are the responsibility of the Health Guidelines Revision Committee (HGRC)—a multidisciplinary consensus body of more than 120 experts on the many issues addressed in the *Guidelines* including clinicians,

administrators, architects, engineers, and representatives from authorities having jurisdiction. The participation of individuals with such a wide range of expertise helps make the document reflective of a variety of clinical, administrative, engineering, and design concerns that is based on interdisciplinary consensus. As previously mentioned, the acoustical criteria are developed by the FGI Acoustics Working Group. This group authors and updates the *Sound & Vibration Design Guidelines for Health Care Facilities* which serves as the sole acoustical reference for the *Guidelines*.

Interdisciplinary consensus is developed through a process that includes public input and three meetings of the full HGRC generally held over a two-year period. The cycle begins shortly after publication of the current edition of the *Guidelines* with a period for public submission of proposed changes. The HGRC then considers the public proposals and proposals prepared by HGRC members and subcommittees, and votes on whether to accept, accept with modification, or reject them.

The result of this committee work is a draft manuscript for the next edition of the *Guidelines* which is made available online for public review and comment. After this review period, the HGRC meets to review the comments on the draft document and finalizes the content for the next edition. A final draft is then reviewed by the Steering Committee and then submitted to the HGRC for final approval by ballot. Subsequently, the next edition of the *Guidelines* is published.

4. EDUCATION EFFORTS

In order to help users stay current with the periodic changes to the *Guidelines*, the FGI and American Society for Healthcare Engineering (ASHE) is offering a series of webinars and workshops to roll out FGI 2014 which began on February 27, 2014, with a one-hour session providing a general introduction to the major changes to the 2014 cycle. It is expected that a variety of additional 1 to 1.5 hour educational webinars and workshops will be offered.

5. CONCLUSIONS

Both the *Guidelines for Design and Construction of Hospitals and Outpatient Facilities* and *Guidelines for Design and Construction of Residential Health, Care, and Support Facilities* serve as industry standard documents for the design and construction of healthcare facilities in the United States and have been utilized in over 60 countries internationally. The incorporation of acoustical criteria in the 2010 cycle both affirms the importance of proper acoustics in healthcare facilities and provides a widely recognized, quantitative set of acoustical criteria which are the only comprehensive acoustical criteria for healthcare facilities written in code language.

Because of the importance to stay current with the evolving research in healthcare design, the *Guidelines* are revised every four years following a formal continual improvement process conducted by the Health Guidelines Revision Committee (HGRC). Many changes relevant to acoustics have been made in the 2014 cycle including the division into two volumes, the identification of acoustics as a life-safety issue, and many changes and clarifications to the acoustical criteria. With increasing evidence of the effects that poor hospital acoustics have on patients and staff, it is expected that future editions of the *Guidelines* will continue to be revised and improved.

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