Relational Data Model for the American College of Radiology Appropriateness Criteria

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This article describes a data model for encoding the American College of Radiology Appropriateness Criteria (ACRAC) for selection of diagnostic imaging procedures. These guidelines are recognized widely as an authoritative repository of "best evidence" concerning appropriate radiology tests for a large number of clinical conditions. In its current text document format, the ACRAC is of limited utility for electronic use. The data model the authors propose completely encodes all attributes and domains of the published guidelines and is suitable for translation into any industry standard relational database system. Additionally, the authors have added mappings onto commonly used procedure (CPT) and clinical problem (ICD) coding systems. When populated with the current ACRAC content, such a database could serve as the "master" repository of the guidelines with changes and additions made via an interface built with standard database application development tools. The database also could be made available for incorporation into existing information systems used for order entry, decision support, compliance tracking, and health services research at regional and national levels.

KEY WORDS: Guidelines, radiology, appropriateness, American College of Radiology, data model, CPT codes, ICD-9 codes

THE DEVELOPMENT and use of guidelines for medical practice has been advocated by influential medical organizations for more than 10 years. These include the American Medical Association and the Institute of Medicine.^{1,2} Hillman³ outlined the need for research and articulated barriers to guideline implementation in radiology. He felt that if recommendations are available only in printed form they tend to be minimally influential in terms of actually altering practice patterns. Dorfman⁴ stressed the importance of assessing current patterns of diagnostic testing utilization, developing guidelines, and performing rigorous

outcomes-based clinical research to determine efficacy of instituting guidelines in routine practice. An essential preliminary step for clinical usage of radiology-specific guidelines is to adapt them to current health care information technology infrastructures. In addition to converting guidelines into machine-readable format, they should be mapped onto preexisting and widely accepted coding schemes. Examples of these are the American Medical Association Common Procedural Terminology (CPT 2001) and International Classification of Diseases, 9th edition, Clinical Modification (ICD-9 CM). These coding schemes represent medical (including radiologic) procedures and clinical problems, respectively, and have been designated as national standards.⁵

The American College of Radiology Appropriateness Criteria (ACRAC) are the only comprehensive North American practice guidelines for diagnostic imaging selection, radiotherapy protocols, and indications for image-guided interventional procedures. They embody the best current evidence for choosing appropriate imaging evaluation and interventional procedures for a large number of clinical conditions. Further, the ACR is fully committed to continuously adding to and updating the content of these guidelines and has developed the infrastructure to carry this out in the fu-

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ture.^{6,7} The ACR initiated its Appropriateness Criteria Project in 1993. The main output of the effort was a collaborative document developed by consensus using the Delphi method by expert panels on diagnostic imaging. This document contains evidence-based best practice guidelines for selection of appropriate diagnostic imaging procedures to address questions arising in a wide variety of clinical settings. By 1999 there were 210 clinicians and scientists serving on 10 panels. These include 35 representatives from 19 specialties other than radiology. The current (2000) version of the document contains over 140 clinical conditions with 820 variants.⁷

The majority of the guidelines represent specific clinical problems. For every variant the panel produced an annotated list of possible imaging procedures that might be used to work up patients presenting with these problems. The annotations to each procedure consist of numbers ranging from 1 to 9 that represent panel consensus about its appropriateness based on balancing cost, risk, and benefit. Higher numbers represent more appropriate procedures. Approximately one quarter of the guidelines relate to radiotherapy or chemotherapy protocols for commonly encountered neoplasms. Variants represent various stages, grades, and treatment histories of specific types of cancer. Radiation therapy expert groups produced lists of treatment regimens annotated with numbers (1 through 9). These represent panel consensus as the most appropriate regimen based of efficacy, cost, and side effects. Again, higher numbers represent more appropriate choices. The smallest subset of the guidelines relate to radiology-guided interventional procedures. Again, the tables codify consensus opinion by the expert panel. For these guidelines, rather than clinical problems, the individual condition tables and variants each represent a specific image guided interventional procedure (eg, percutaneous abdominal abscess drainage). The row entries in each table represent results of preprocedure clinical, laboratory, and imaging findings that would be used in deciding whether to undertake the intervention. The 1 through 9 score represents the weight of the listed indication. Higher numbers mean that the presence of the indication strengthens the case for doing the procedure.

Currently, the ACRAC is available from the ACR in book format, as portable document format (PDF) files on CD-ROM or via their web site and in a file suitable for loading onto a personal digital assistant (PDA). The only other computer-readable format consists of pre-press document files in Microsoft Word format. These are available from ACR to authorized development partners. To allow for subsequent usage of the ACRAC in health services research or incorporation into clinical information systems, the content must be rendered into structured machine-readable form (ie, a relational database). This article outlines potential uses of, functional requirements for, and the general form of a relational data model for encoding the ACRAC. The structure of the current ACRAC document will be deconstructed and used to describe an entity relationship diagram that includes a complete mapping onto the ICD-9 CM and CPT 2001 coding schemes. The scope of subsequent discussion in this article will be limited to guidelines specific to imaging procedure selection for well-defined clinical problems. These represent the majority of the ACRAC content and are not available elsewhere (certainly not with such complete scope of coverage). Radiotherapy protocols are duplicated in several other venues, most notably the Radiation Therapy Oncology Groups. The interventional procedure guidelines are intrinsically different in their basic form and represent only a minority of the ACRAC content.

USES FOR DATABASE

Several functions of a database containing the ACRAC may be articulated. First, and perhaps most importantly, is as the primary repository of content. This master copy would be housed at ACR headquarters. Once the current documents are parsed into the database format, updates would be applied directly to it via a specialized interface available to ACR staff. Additions to the guidelines would be collaboratively authored via a secure web-based architecture connected to the database. The Delphi consensus process also could be conducted on line during guideline development. A second use for the database would be to enable health services researchers to perform utiliza-

tion analyses using available administrative data sets. For example, we plan on comparing ACRAC scores for various conditions and imaging procedures with current Medicare reimbursement tables. The mappings onto ICD-9 and CPT code sets will be vital to this effort because the Medicare tables consist entirely of pairings of these codes. The ACR has developed a service available to its members called *Utilization Analysis*. Procedure billing data are submitted to ACR on a quarterly basis, and statistical abstracts are returned detailing the extent of appropriate use of procedures.⁸ Clearly, having the ACRAC in database format would allow ACR to better automate and expand this offering.

Another use for a machine-readable form of the ACRAC is to facilitate incorporating the guidelines into order entry modules of hospital and radiology information systems (HIS and RIS, respectively). On-line radiology order entry is needed to insure proper choice of imaging procedures and to reduce overutilization. There is growing evidence that when guidelines are presented to physicians at the time of order entry, tests are better suited to clinical needs, errors are decreased in frequency and severity, and overall volumes of tests and treatments may be reduced.^{9,10} The results of such interventions on radiology test volume and appropriateness have been encouraging, though somewhat mixed.¹¹⁻¹⁴ Even if outcomes are only marginally improved, robust on-line radiology order entry systems serve to move the function of coding the clinical justification for procedure billing to the "front end" of the process. This is vital because proper indication codes (ICD-9) provided by ordering physicians are the only way to insure third-party reimbursement for all procedures.¹⁵ The ACRAC are well suited for this function because they are already organized into commonly encountered clinical presentations with associated imaging procedures graded by appropriateness. Integration of the guidelines with ICD-9 and CPT code sets will be vitally important because these provide common nomenclature with existing order entry, scheduling, and billing processes. All HIS and RIS software has at its core a large capacity relational database, and the ACRAC content must be available as such to be of any use to

these systems. In the future, we hope to see a totally integrated information flow starting with physician order entry, continuing through examination scheduling and protocol specification, culminating with a problem and examination-specific structured report template directly linked to the image review (PACS) software.¹⁶

DOCUMENT CONTENT AND STRUCTURE

Members of RSNA will be familiar with the hard copy version of the ACRAC having received them as a supplement to the journal *Radiology*.¹⁷ The identical content is available on a companion CD-ROM disk. It is encoded into encrypted portable document format (PDF) and may be viewed or printed. The PDF format must be viewed with an application specifically designed to disallow any attempt at copying the text to other formats. These same PDF versions of the ACRAC may be viewed from the ACR website at the following address: http://www.acr.org/departments/appropriateness_criteria/text.html. We were able to obtain the same content through special arrangement with the College in the form of Word documents (Microsoft Corp, Redmond Washington) on a CD-ROM. Each guideline is contained in a single document formatted and ordered in identical fashion as the hard copy. These files are the prepress working versions of the printed guideline book.

As described above, the majority of the ACRAC content pertains to image procedure selection for specified clinical conditions. We will limit discussion to these guidelines that occupy the first 980 of 1,512 pages in the book. They are divided into chapters based on organ system: cardiovascular, gastrointestinal, musculoskeletal, neurologic, thoracic, urologic, pediatric, and women's imaging. These chapters contain from 4 to 23 uniquely named guidelines (eg, first entry in Cardiovascular Imaging: Acute Chest Pain-Suspected Aortic Dissection).

Table 1 shows the basic content of an individual guideline. The component structure and ordering is identical across all organ systems and guidelines. Every guideline has at least one table of imaging procedures with associated appropriateness scores. Multiple tables within a

Table 1. Structure of a Single ACR Appropriateness Criteria Entry

Name	Description and Comments	Always Present
Title	Appears at start of criteria and uniquely identifies it.	Yes
Panel name	Gives the title of the expert panel that generated the guideline.	Yes
Guideline contributors	Lists panel members that wrote the guideline. Each member identified with number that refers to information in first page footnote (see below)	Yes
Summary of literature review	Narrative summary of relevant literature. Numbered references listed at end of guideline.	Yes
Anticipated exceptions	Lists clinical situations that may fall outside the guideline.	Yes
Review information	Gives year of initial guideline development and year of next formal review.	Yes
Contributor details	Footnote on first page. Lists contributor institution and role in guideline development.	Yes
Definitions	Lists terms used in literature review and condition tables and gives specific definitions.	No
Ancillary documents	Tables, graphs, or drawings referred to in review of literature section.	No
Clinical condition	Lists the general condition for which the guideline is intended. Often similar to the title.	Yes
Variant descriptions	Lists specific variants of the clinical condition covered by the guideline.	No
Appropriateness table(s)	Lists possible examinations for each condition/variant with appropriateness score.	At least one
Practice area	Running footer. Lists practice area (e.g. Neurologic, Urologic).	Yes
Short title	Running footer. Short version of guideline title.	Yes
References	Lists references used in guideline development as cited in the review of literature.	Yes

guideline are identified as numbered variants under a single clinical condition. Therefore, each imaging procedure selection list may be uniquely identified with a variant number and name within a guideline for a single clinical condition. These lists or tables constitute the core content of the document and for many uses may be all that is needed. One potential problem that we have noted while examining the document is that there is considerable inconsistency of naming imaging procedures between guidelines. For example, the following table entries found in different guidelines all refer to abdominal computed tomography: Computed Tomography: Contrast-Enhanced CT, CT, CT Abdomen, and Rule Out Liver Metastases: Computed Tomography. The data model along with mapping to CPT codes that we articulate below would obviate such inconsistencies.

Other substantive content consists of narrative review of literature with reference citations, tables of definitions, and ancillary documents. Contributors originate and edit these portions during development and modification of content. Users of the guidelines wishing to understand the evidence utilized by panel members during consensus development may consult the narrative review and referenced articles. During

guideline development, some of the expert panels found it useful to explicitly define certain terms used in the narrative review and guideline tables for purposes of clarity. These are included after the narrative review section when present. For example, the guideline for imaging in epilepsy has a list of definitions including seizure, provoked seizure, and partial seizures among others. Ancillary documents are located after the narrative review when appropriate. These may consist of tables, figures, and graphs. The seizure guideline mentioned above lists the International Classification of Epileptic Seizures and Syndromes in tabular format. These would be considered to be ancillary documents in this data model.

Another type of content may be called administrative, and it is located mostly at the beginning of each guideline or within a running footnote. This consists of the expert panel name, individual contributors with institutional affiliation, and their roles in development of the guideline. Anticipated exceptions to each guideline, the date of original development, and scheduled review date are located between the narrative section and the condition/variant tables. Although this information may not be of immediate concern to many users for their

Table 2. Field Structure and Sample Data from the Base Table (Guidelines)

Field Name	Sample Data 1	Sample Data 2
Guideline_ID	2	3
Page_In_Book	205	579
Guideline_Title	ACUTE PANCREATITIS	ORBITS, VISION, AND VISUAL LOSS
Short_Title	Acute Pancreatitis	Visual Loss
Body_Area	Gastrointestinal	Neurologic
Panel_Name	Expert Panel on Gastrointestinal Imaging	Expert Panel on Neurologic Imaging
Summary_Literature	This topic focuses on the diagnosis and initial evaluation of patients with suspected or known acute pancreatitis... and so on	Primary diseases of the orbit may present with proptosis with or without visual disturbances and so on
Anticipated_Exceptions	None	None
Original_Developed	1998	1999
Next_Review	2002	2002

Table 3. Example of a Single Variant Table as Formatted in the ACR Document (Clinical Condition: Orbits, Vision, and Visual Loss: Variant 7: Young adult patient with recent head injury and blindness)

Radiologic Examination Procedure	Appropriateness Rating	Comments
CT	8	Usual ferromagnetic precautions.
Magnetic resonance imaging	8	
Plain films	5	
CT with contrast	4	
MRI with contrast	4	
MRA	4	
Doppler sonography	2	

NOTE. Appropriateness criteria scale: 1, 2, 3, 4, 5, 6, 7, 8, 9 where 1 = Least appropriate and 9 = Most appropriate.

specific clinical question, it is needed to accurately document the source and timeliness of the opinions contained in the guidelines. Further, inclusion of these items conforms to well-recognized recommendations for medical guideline structure and content.^{18,19}

THE DATA MODEL

The base table in the database contains a single entry for each guideline and is called *GUIDELINES*. The fields in this table contain identifying information unique to each guideline including the formal title, a short title, the body area or organ system, the expert panel name, and the beginning page in the hard copy document. The primary key is an integer number called *Guideline_ID* and would be assigned automatically at initial entry. Other fields contain the anticipated exceptions, date of initial development, and date of review. The narrative review of literature could be contained in a field capable of holding a large amount of text

(called a memo type in some databases) or be in a separate document with a pointer in the *GUIDELINES* table to its physical location. The latter choice would allow the narrative reviews to be developed in word processor format thus enabling full use of the sophisticated features of these programs. Table 2 lists the field structure and shows sample content of the base table.

The core diagnostic imaging content of the ACRAC consists of lists of radiologic procedures and their relative appropriateness with respect to specific clinical problems or variants. Table 3 depicts the format and content of one such variant table contained in the “Orbits, Vision and Visual Loss” guideline. Note that only the imaging technique is listed, whereas the body area examined must be inferred from the scope of the guideline and variant under consideration. The examination details need to be specified more explicitly and consistently in the database. This information requires 3 tables to encode. These are *CONDITIONS*, *PROCE-*

Fig 1. Entity-relationship diagram of tables encoding the core guideline content. The page_in_book fields in GUIDELINES and CONDITIONS are mostly for reference with the current printed document and may be omitted in future.

DURES and a linking table between them (CONDITION_PROCEDURE). Entries in the CONDITIONS table map directly to clinical variants within each guideline. The linking table encodes the central organizing structure and contains one record for every row in the appropriateness rating lists. The names for procedures given in the original document are stored in the linking table (DESCRIPTION field) along with the appropriateness rating number. The PROCEDURES table would have one entry for every unique imaging study, thus providing standardization of procedural nomenclature and allowing unambiguous mapping to CPT codes. Figure 1 is an entity relationship (ER) diagram of these 3 tables, the base (GUIDELINES) table, as well as the ICD and CPT code specific tables.

The ICD and CPT code sets are mapped to the core content tables containing the unique CONDITIONS and associated uniquely defined PROCEDURES. A linking table (PROCEDURE_CPT) connects procedures and CPT codes. Each procedure may link to one or more CPT codes. For example, a four vessel cerebral arteriogram would link to CPT codes for arterial puncture and catheterization as well as for selective injection of each vessel. The ICD code linking has the potential to be rather more complicated. First, a clinical condition variant may have several pertinent ICD codes, and these may be of different importance. For instance, one of the variants of Acute Pancreatitis

reads “Severe abdominal pain, elevated amylase lipase, no fever or evidence of fluid loss at admission.” Obviously, we would want to assign the code for acute pancreatitis as “primary.” There are 3 other positive indications—abdominal pain, elevated amylase, and elevated lipase—that each have their own ICD code. However, there are also 2 negative statements—no fever and no evidence of fluid loss—that have ICD codes for the presence of the sign. One can articulate a hierarchy of related ICD codes: primary, secondary, and negatives to cover these situations, and this is the purpose of the CODE_LEVEL field in the CONDITION_ICD9 table as shown in Figure 1. A final consideration about ICD codes is that there may be several words or phrases that map to the same code number. Although not shown on Fig 1, a separate table could serve to store any number of desired synonyms for each code number. The descriptive text in the ICD9_CODES table itself would contain the “official” nomenclature as promulgated by the World Health Organization. Table 4 lists the same variant depicted in Table 3 because it would be stored in the database complete with ICD-9 codes, standardized procedure nomenclature, and CPT codes.

A single table suffices to encode the literature references cited in narrative summaries contained in each guideline. This table includes extra fields to contain data not specified in the original ACRAc documents. Literature refer-

Table 4. Example Variant Table Complete With Standard Procedure Names, ICD-9 Codes, and CPT Codes

Neurologic Imaging: Orbits, Vision, and Visual Loss	
Variant 7: Young adult patient with recent head injury and blindness	
ICD-9 CODES FOR VARIANT	
(primary) 368.11	Visual loss, sudden
(secondary) 959.01	Head injury, unspecified
PROCEDURES WITH CPT CODES	
8-CT HEAD [Head and orbits, unenhanced]	
70450	Computerized axial tomography, head or brain; without contrast material
70480	Computerized axial tomography, orbit, sella, or posterior fossa or outer, middle, or inner ear; without contrast material
8-MRI HEAD [Head and orbits, unenhanced]	
70540	Magnetic resonance (eg, proton) imaging, orbit, face, neck
70551	Magnetic resonance (eg, proton) imaging brain (including brain stem); without contrast material
5-X-RAY HEAD [Skull series, orbital series]	
70200	Radiologic examination; orbits, complete, minimum of four views
70250	Radiologic examination, skull; complete, minimum of four views, with or without stereo
4-CT HEAD [Head and orbits, enhanced]	
70470	Computerized axial tomography, head or brain; without contrast material, followed by contrast material(s) and further sections
70482	Computerized axial tomography, orbit, sella, or posterior fossa or outer, middle, or inner ear; without contrast material, followed by contrast material(s) and further sections
4-MRI HEAD [Head and orbits, enhanced]	
70540	Magnetic resonance (eg, proton) imaging, orbit, face, neck
70553	Magnetic resonance (eg, proton) imaging brain (including brain stem); without contrast material, followed by contrast material(s) and further sequences
4-MRI HEAD [Magnetic resonance angiography, MRA]	
70541	Magnetic resonance angiography, head and/or neck with or without contrast material(s)
2-US HEAD [Orbital Doppler sonography]	
93882	Duplex scan of extracranial arteries; unilateral or limited study

ences are only cited in standard citation format including authors, title, journal, year, volume/number, and page range. We have expanded these reference fields to contain all the information specified in Medline records. These include the abstract, keywords, and medical subheading (MESH) terms. The PubMed (PM_ID) and universal (U_ID) identifying numbers allow cross referencing to the Medline database. As references become available in on-line form, the identifying numbers will enable directly linking to an electronic version of each article from the publisher or other sources. If copyright issues could be worked out, copies of the full text documents might be stored along with the database for immediate access by users of the ACRAC database and during subsequent guideline development and review. A second

table holds information about contributors to the guidelines. At this time there are more than 200 individuals involved in developing the guidelines. Each guideline has from 8 to 20 contributors organized into expert panels. This information is part of the published guidelines and also will be useful to ACR for ongoing guideline development and communication. In a table called *CONTRIBUTORS* we have expanded the published names and institutions to include complete contact information. Because both references and contributors may be common to several guidelines, linking tables serve to relate them back to the GUIDELINES base table. Figure 2 shows the relationships between guidelines, references, and contributors.

Other guideline content is encoded in 2 additional tables. One of these, called *ANCIL-*

Fig 2. Entity-relationship diagram of tables encoding guideline contributors and references cited in the literature summaries.

LARYDOCS, is linked directly to the base table with a one-to-many relationship and contains pointers to files containing any tables, graphs, or figures. The other table is called *DEFINITIONS* and contains any potentially ambiguous terms that contributors feel need to be explicitly defined. As with many of the other concepts described above, definitions may be shared by several guidelines, and a linking table serves to encode this. One clear advantage of storing and linking definitions in this manner is to avoid duplication of terms between guidelines with different definitions. Figure 3 depicts the relationships between guidelines, ancillary documents, and definitions.

DISCUSSION

Other workers, including Kahn et al²⁰ have explored the problem of encoding the ACRAAC to enable widespread dissemination via the internet. Their realization has some similarities with the one we have articulated. Among these, was the requirement to define ‘canonical’ forms for the names of imaging procedures so as to provide standardized names across the various guidelines. In Kahn’s schema, the basic entities of conditions with variants and procedures are defined in a standard generalized markup lan-

guage (SGML) document type definition (DTD). These serve to encode the core ACRAAC content and are analogous to the *CONDITIONS* and *PROCEDURES* tables shown in our Fig 1. To provide for robust navigation within and between guideline content, Kahn developed an ontology editor and browser for terms that relate to the conditions.²¹ These terms may be linked with external vocabularies such as the Unified Medical Language System (UMLS).²² In our schema, this function is served by including links to the ICD-9 code set as shown in Fig 1.

Although our implementation of the ACRAAC as a database is complementary to Kahn’s, there are differences that may have advantages for specific applications. First is the concept of linking to the disease classification used in almost all health care organizations in the United States (ie, ICD-9 codes). As described above, an auxiliary table of synonyms to the standard ICD-9 code nomenclature would be easy to add to our data model, thus increasing expressiveness. We have done this with the coding software used by our clinical radiologists with great success.²³ Similarly, linking to CPT codes is vital so as to allow integrating the ACRAAC material into information systems used by health service researchers, regulators, payers, and providers.

Fig 3. Entity-relationship diagram of tables encoding definitions of terms and ancillary documents included in some of the guidelines.

Our data model is described in terms of relational database tables, relationships, and views. As such, it would be easily incorporated into existing radiology information systems and billing software because these basically are database management systems. In the next decade, electronic physician order entry (POE) for radiology studies will become more widely available. Pilot implementations of such systems have shown great promise for improving patient care and reducing cost.²⁴ The ACRAC is an obvious choice for the medical content underlying decision support and compliance logic in radiology POE software. Here again, the guidelines should be available in relational database form with links to ICD and CPT codes to allow them to be incorporated into existing hospital information systems.

Kahn has emphasized the importance of a shared “master” repository of radiology appropriateness criteria.²² The ACR is the obvious organization to maintain the “master” version of the ACRAC and currently does so in the form of text-oriented documents. We specifically added several tables to the data model to facilitate maintenance, expansion, and dissemination of the guidelines by ACR. These include literature references, definitions, ancillary documents, and contributors directly corresponding to entities found in the current documents developed by the ACR. These tables (depicted in Fig 2 and 3) are not needed for routine clinical use of the ACRAC. However,

when fully populated and combined with the core content tables (Fig 1), each guideline can be exactly reproduced in the same format as originally written.

With complete encoding of the ACRAC including literature references, novel ways to organize and utilize the content become possible. For example, by means of a simple query, one could obtain a list of all referenced articles pertaining to a particular disease, symptom, or procedure. Likewise, one might generate a list of procedures (CPT codes) with all associated indications (ICD codes) as specified in the guidelines with the associated appropriateness score. Such a listing would be directly comparable with CPT/ICD tables routinely published by Medicare and other payers to detail reimbursement policy. It will be very interesting to compare these to see to what extent Medicare would consider the procedures deemed appropriate by ACR as payable.

We have described a relational database schema for completely encoding the American College of Radiology Appropriateness Criteria for diagnostic imaging. When fully populated and enabled with an appropriate user interface, the database could serve as the master repository for the guidelines. To this end, we have shared this work with the ACR and will continue to do so. Our data model includes mappings onto the standard ICD and CPT code sets, which should allow use in a wide variety of health information systems. The prototype

version is available to interested readers as a blank Microsoft Access database. Links to download the appropriate files may be found at <http://www.xray.ufl.edu/sistrom>.

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