

**Keyboarding data entry, carpal tunnel syndrome cause, treatment and co morbidities–  
Literature Review supplement as of September 2010****Purpose**

The purpose of this literature review is to consider the scientific evidence associated with the relationship of carpal tunnel syndrome, cause and treatment, and keyboarding. Some flexion and extension of fingers is required in the use of personal computer keyboarding, that is, depressing buttons or keys for data entry and word processing.

- 1 *Does the literature support the use of keyboarding as relational cause of carpal tunnel syndrome?*

Answer – The literature is inconclusive as to whether keyboarding is a cause of carpal tunnel syndrome. The literature identifies a dozen dozen other maladies, which were associated as causes of carpal tunnel syndrome, which maladies, as causes, are listed in the Appendix of Definitions.

- 2 *What are the treatments for carpal tunnel syndrome among keyboarding patients?*

Answer – The literature identifies, among others, wrist bands, physical therapy, physical exercise, acupuncture, surgery (termed carpal tunnel release), drugs (steroids, pain killers), QWERTY layout split keyboards (each half of the layout bent at an angle to the other half), QWERTY sloped keyboards, work reassignment to non keyboard activities (i.e. stop typing), and don't grow old.

- 3 *What is the significance of carpal tunnel syndrome with co morbidities?*

Answer – As of 2000, among the estimated two and a half millions of studies indexed, none compared carpal tunnel syndrome with other co morbidities.

Claims in this application note that the loss of tactile sensation, due to pain, numbness, and tingling, in the upper extremities, have an impact on breast cancer self identification, impact on other skin cancer self identification, dental hygiene which also relates to heart disease, chemical adjustments due to self medication for pain, and mental health.

- 4 *Can the symptoms of carpal tunnel syndrome be prolonged, delayed?*

Answer – The 1995 Flannery study compared QWERTY, Dvorak and Finger Relief and determined configuration of the layout could reduce stress due to unnecessary finger flexion and extension.

Symptoms can also be prolonged with drugs, or shifting work from flexors extensors to inter osseous<sup>ii</sup> and lumbical muscles.<sup>iii</sup>

- 5 *What keyboard layout arrangements have affected the health of users?*

Answer – Among QWERTY, DVORAK, Finger Relief, and 100 other patented keyboard layouts, the discussion of user health has not associated the syndrome with the layout, except as previously noted in the 1995 Flannery study. Layout arrangements have been ignored because everything is QWERTY.

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6 *Can the severity of symptoms of carpal tunnel syndrome be reduced?*

Answer – Yes. The 1995 Flannery study suggested the Finger Relief and Dvorak keyboard layouts would reduce the severity of the body's response by reduced flexion and extension of the fingers.

**Other topics**

The articles were divided between:

- 1) those outlining treatments for carpal tunnel syndrome
- 2) those discussing causes of CTS
- 3) those discussing or mentioning QWERTY, Dvorak's Simplified Keyboard, alternative layouts (split or saddle keyboards), and Finger Relief keyboard layout.

There are about 100 patented types of keyboard layout arrangements, which, as a convenience and demonstration, have divided into 2 categories – Category Blue, inefficient and Category Yellow, efficient.

*Category Purple – Inefficient Layouts*

Sample QWERTY layout

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1 2 3 4 5 6 7 8 9 0
Q W E R T Y U I O P { }
A S D F G H J K L ; '
Z X C V B N M , . ?

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The intentionally inefficient layout is QWERTY. In lieu of QWERTY, any other layout which places or keeps the most frequently used letters in the local language away from the home row, so as to maximize flexion and extension, delay and slow data entry, and delay and slow training, is an inefficient layout. Inefficiency is characterized by making it harder, more difficult and slower to learn finger placement, by maximizing finger extension and flexion, slowing typing speed, increasing pain, tingling and numbness, which are also symptoms of carpal tunnel syndrome. Most prominent layout is QWERTY,<sup>iv</sup> a name derived from the six keys on the upper row of letters beginning in the left corner. The most used letters in English are on the upper or lower rows (E T N R O I), with least used letters and punctuation on the middle row (F G J K colon, and apostrophe).<sup>v</sup> Most data entry is on the left hand (because the E and T letters are one fourth of the letter frequency usage in English), for an efficiency of about 20 percent. Schools' typing classes often allow about 18 weeks to learn touch typing on QWERTY as the exercise of flexion wearies the typing students' forearms and wrists, thus limiting daily training to an hour or less. Qwerty is ubiquitous and therefore convenient, for those having to use keyboard in different locations, such as home, library, school and work.

The inefficient keyboards' categories may be further divided into 2 additional subcategories, Subcategory Blue non-alternative and Category Red, alternative.

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*Subcategory Blue – non alternative inefficient – QWERTY*

1 2 3 4 5 6 7 8 9 0  
 Q W E R T Y U I O P { }  
 A S D F G H J K L ; '   
 Z X C V B N M , . ?

A subcategory Blue non alternative keyboard has either a tiered, like a 20<sup>th</sup> century typewriter, or flat set of keys, like a laptop or notebook, using the QWERTY layout or any other inefficient configuration. For exact rendering see the original patent application.

*Subcategory Red – alternative inefficient – QWERTY*

Q W E R T    Y U I O P { }  
 A S D F G    H J K L ; '   
 Z X C V B    N M , . ?

The subcategory Red is for an alternative keyboard. Alternative is the term previously used for 'split' keyboards, whose layout leaves a space in the middle of the layout (usually between the numbers 5 and 6, T and Y, G and H, and B and N,) relying on the theory that hands coming together in the middle of the lap or chest are at an angle to the wrist and forearm, and reducing the angle between wrists, by increasing the angle between layout lines, is superior. The split keyboard theory was patented in the 1970s, but any clinical comparison studies, if existing, are so obscure as to be undetected and unavailable for evaluation. For a more exact rendering see the original patent application.

*Category Yellow – efficient layouts – FINGER RELIEF and DVORAK*

An efficient keyboard layout is one which places or keeps the most frequently used letters in the local language on the home row, so as to minimize flexion and extension, and speed data entry. These are in English E T N R O I A S D H L. These reduce by half the distance fingers move to enter data. Efficient keyboards, with a minimum amount of finger extension and flexion, permit faster typing speeds. These layouts are 80 percent efficient. Reduces distance fingers move to enter data by half. These keyboards are also associated with a reduced workers' compensation claims and absenteeism as compared to QWERTY keyboarding.

The efficient keyboard layouts can be divided into 3 subcategories, Orange, green and gold.

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*Subcategory Orange – efficient and alternative and QWERTY (red) mindful – FINGER RELIEF TheOrdinals (Orange)*

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1 2 3 4 5 6 7 8 9 0
Q W F G J Y U K ; P [ ]
A S D E I H O T L R N
Z X C V B ' M , . ?

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Subcategory Orange is a layout which is efficient (Yellow) and alternative (red). A subcategory orange maintains the maximum QWERTY layout with a split array. This is accomplished by moving or rearranging the minimum letters required for the most efficiency, while preserving all the punctuation and the rest of the QWERTY layout in order to reduce retraining time and inconvenience. Thus 21/33<sup>rd</sup>s are retained in their QWERTY century old location, relative to the other keys. Prolonged onset of pain, tingling and numbness, reduced severity of symptoms of carpal tunnel syndrome

Unique among subcategory orange is the Finger relief keyboard.

*Subcategory Green - efficient, non alternative and QWERTY (blue) mindful – Finger Relief (Green)*

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1 2 3 4 5 6 7 8 9 0
Q W F G J Y U K ; P [ ]
A S D E I H O T L R N
Z X C V B ' M , . ?

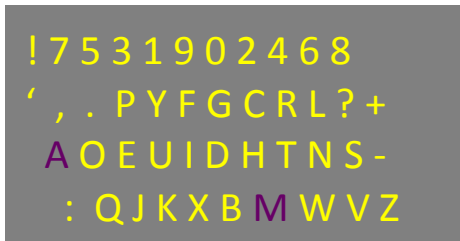
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Subcategory Green is a layout, which is efficient (yellow) and not alternative (blue). A subcategory green maintains the maximum QWERTY layout with a flat parallel key layout. As with orange, this is accomplished by moving or rearranging the minimum letters required for the most efficiency, while preserving all the punctuation and the rest of the QWERTY layout in order to reduce retraining time and inconvenience. As with orange, 21/33<sup>rd</sup>s are retained in their QWERTY century old location, relative to the other keys.

Unique among subcategory green is the Finger relief keyboard.

Orange and green layouts allow the typist to maintain maximum psychokinetic memory in their fingertips, (i.e. touch typists) so as to shorten re-training time, utilizing much of the previous knowledge and experience.

*Subcategory Gold – efficient and QWERTY (purple) unmindful – Dvorak Simplified*



Subcategory Gold are efficient layouts (Yellow), which substantially ignore the QWERTY layout, the most prominent layout of which is Dvorak's simplified keyboard.<sup>vi</sup> Subcategory gold layouts ignore the QWERTY layout and rearranged 13/14<sup>th</sup>s or more of the letters, and punctuation. Thus 2/33<sup>rd</sup>s or 2/44<sup>th</sup>s are retained in their QWERTY century old location relative to the other keys. Gold layouts are changed from QWERTY by 120 percent (moving overwhelmingly the letters and all punctuation, retaining none to two or few letter previous locations). The result is that prior competence or expertise with the QWERTY layout must be discarded and the finger movement must be retrained in its entirety. Because of the retraining, these subcategory gold layouts have been objected to as not recovering the cost of retraining. Dvorak layout was associated with reduced workers' compensation claims and absenteeism as compared to QWERTY keyboarding. Version displayed is from Wikipedia. For exact rendering see the original patent applications.

Government health organizations<sup>vii</sup> recommend the following for reviewing the published literature for health science.

1. Published authoritative evidence derived from definitive randomized clinical trials or other definitive studies; and,
2. General acceptance by the medical community (standard of practice), as supported by sound medical evidence based on:
  - a. Scientific data or research studies published in peer-reviewed medical journals; or,
  - b. Consensus of expert medical opinion (i.e., recognized authorities in the field); or,
  - c. Medical opinion derived from consultations with medical associations or other health care experts.

#### *Evidence Evaluation*

A list of articles or abstracts, both medical and general, is given in the attached tables. The articles are collected by topics - to wit, treatment and clinical trials for carpal tunnel syndrome, the causes of carpal tunnel syndrome, and keyboard layouts.

**Position Statements****Article on keyboard layouts and carpal tunnel syndrome.**

See (3)-Quantification of Tendon Excursion through Kinematic analysis of typing movements on alternative keyboard layouts- 19th annual meeting of the American Society of Biomechanics-1995. NASA, Leland Stanford Junior University, California 24-26 August 1995, University of Pittsburgh Medical Center Division of Physical Medicine and Rehabilitation Sep 29, 1995. Dr. Rick Robertson, MM Flannery, RA Cooper. Department of Veterans Affairs Medical center, California State University, Sacramento. Partial funding by the U.S. Department of Education, Rehabilitation Services Administration. Results discussion. Subjects 1 and 2 showed consistent results with the DVORAK and ASINREDHOT layouts requiring less total tendon excursion than typing on the QWERTY layout. Evidence suggests that excessive excursion can induce trauma to the connective tissue structures resulting in tendinitis and edema. \*\*\* causing symptoms typically ascribed to carpal tunnel syndrome. BY minimizing range during repetitive motion one may reduce tendon excursion and reduce the probability of cumulative trauma. 399-402, 653-657

**Reviews of articles on causes of carpal tunnel syndrome.**

See (1711) 'Upper extremity disorders a literature review to determine work-relatedness [J Hand Surg Am. 1995] – PubMed. The objective of this review is to establish whether the medical literature validates a causal relationship between upper extremity disorders and work activities. Only 14 of 52 reviewed articles were felt to encompass medical criteria. However, these articles also contained what appear to be major validity flaws. Very little of the written material dealing with the issue of work-related upper extremity conditions incorporates what are felt to be sound medical diagnostic criteria in the definition and identification of these conditions. None of the reviewed studies have established a causal relationship between distinct medical entities and work activities,'

See (1757) Workplace risk factors and occupational musculoskeletal disorders, Part 1: A review of biomechanical and psychophysical research on risk factors associated with low-back pain. [AIHAJ. 2000]

(1729) 'Workplace risk factors and occupational musculoskeletal disorders, Part 2 A review of biomechanical and psychophysical research on risk factors associated with upper extremity disorders [AIHAJ. 2000 Mar-Apr] – PubMed The National Institute for Occupational Safety and Health performed a comprehensive review of over 600 epidemiological studies in 1997 and concluded that there was evidence of a causal relationship between workplace exposures to forceful exertions, repetition, awkward posture, and vibration and disorders of the neck, shoulder, and upper extremities. Although epidemiological studies provide important insights to understanding the causes of work-related overuse disorders, they are sometimes criticized for their inability to measure precisely how people respond to specific risk factors found in the workplace. This article presents a review of recent laboratory studies and biomechanical models of work factors believed to be associated with increased risk of upper extremity injuries and disorders. Biomechanical models and laboratory studies do not replace epidemiological studies. However, these approaches provide important complementary information that is needed to understand the complex process of how exposures to physical risk factors result in strain that may ultimately lead to injury or disease. These studies also provide

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important insights as to how people react and respond to specific physical risk factors found in the workplace.'

### **Reviews of articles on treatment and diagnosis of carpal tunnel syndrome.**

See (1743) 'AHRQ Diagnosis and Treatment of Worker-Related Musculoskeletal Disorders of the Upper Extremity 62 - This report is a systematic evaluation of the evidence pertaining to a broad range of issues related to the diagnosis and treatment of worker-related upper extremity disorders (WRUEDs). For the purposes of this report, "worker-related" is defined as a disorder that affects workers, not as a disorder necessarily caused by work. Four disorders are the focus of this report; carpal tunnel syndrome. 13 questions. Costs of CT release \$8200, endoscopic release of the transverse carpal ligament is \$849.84, short arm static splint is \$72.69

Question 2: Are there specific patient characteristics and/or disease conditions that favor one type of keyboard layout over another? Typists / patients either have symptoms of carpal tunnel syndrome, or they do not. The characteristics of the syndrome are separately discussed, but it is notable that the gender and age of onset, women over 40, is also the age of increased risk for breast cancer. Thus typists who are at risk for breast cancer, other skin cancers, heart disease, eye treatment, dental disease, disability, pain, surgery, and upper extremity disorder, are those who should receive the Finger Relief keyboard.

A. Published authoritative evidence derived from definitive randomized clinical trials or other definitive studies

Answer: The 1995 Flannery study did not involve Carpal tunnel syndrome patients. While the support of a QWERTY keyboard layout device wavers, information on patient selection (other than having carpal tunnel syndrome), frequency of treatment, treatment duration and favorable outcomes utilized are lacking.

B. General acceptance by the medical community (standard of practice), as supported by sound medical evidence based on:

1) Scientific data or research studies published in peer-reviewed medical journals

Answer: Yes. The scientific data published research, 1995 Flannery, supports efficient keyboard layouts, to wit; Finger Relief and Dvorak, over QWERTY. There have also been about a hundred patents improving efficiency on the QWERTY keyboard layout.

2) Consensus of expert medical opinion (i.e., recognized authorities in the field);

Answer: Among Medical authorities No.

Among governmental agencies and corporations, yes.

At different periods, the United States Navy, United States Air Force, AT&T, and IBM, all attempted to replace QWERTY with DVORAK. Each attempt had its limitations, and as a result none succeeded, and all were abandoned. Each knew QWERTY was poor or wrong headed, but there was never any tie in to health issues, which were overlooked or rejected. Since there is no consensus of the expert medical opinions reviewed that one type of keyboard layout is more

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efficacious than another, there is similarly no consensus on which patients should use a particular type of keyboard layout.

3) Medical opinion derived from consultations with medical associations or other health care experts.

Answer: No. Review of medical association statements and position papers from health care experts in the treatment of CTS have no statements regarding the use of an efficient keyboard layout with a specific type of patient or disease process.

### **Summary**

This scientific literature review has collected material showing the different types of treatment for carpal tunnel syndrome. The material also lists suggested causes. But whatever the cause, are there specific patient characteristics or disease conditions which merit the use of one treatment over another? The conclusion is that non invasive is preferable to the invasive, and the tested is preferable to the untested and speculative. Presently the overwhelming number of treatments are not tested.

There is no available evidence for the comorbidities with carpal tunnel syndrome. Included in the attached, are peer-reviewed, published clinical trials, guidelines and consensus statements from clinical experts and medical associations, position statements from organizations with expertise in the subject of carpal tunnel syndrome treatment and technology.

With regard to the quality of the evidence, some authors commented that the studies supporting carpal tunnel syndrome treatments have major validity flaws.

For keyboard comparisons, there is the 1995 Flannery trial (3). Otherwise, there are none to few randomized, prospective, controlled trials. Such information that is reported is statistical. Most expert opinion and consensus lacked specificity.

In summary, the scientific data and literature to date has been reviewed on occasion. QWERTY layout is universally known as an impediment. DVORAK has retraining issues. Finger Relief has the efficiencies of DVORAK, but not the retraining issue. Previous efforts to change layouts have not succeeded.



<sup>ii</sup> The dorsal interossei of the hand are muscles that occupy the space between the metacarpals. There are four dorsal interossei in each hand. They are specified as 'dorsal' to contrast them with the palmar interossei, which are located on the anterior side of the metacarpals.

The dorsal interosseous muscles are bipennate, with each muscle arising by two heads from the adjacent sides of the metacarpal bones, but more extensively from the metacarpal bone of the finger into which the muscle is inserted. They are inserted into the bases of the proximal phalanges and into the extensor expansion of the corresponding extensor digitorum tendon. The middle digit has two dorsal interossei insert onto it while the first digit (thumb) and the fifth digit (little finger) have none. The primary action of the dorsal interossei is to: flex the metacarpophalangeal joint (MCP) and to extend the interphalangeal joints and thus assist the lumbricals. In addition, a secondary function is to abduct the fingers away from the middle finger. This is in contrast to the palmar interossei, which adduct the fingers. This is often remembered by the mnemonic DAB PAD, short for "Dorsal ABducts, Palmar Adducts.

The palmar interossei (interossei volares) are small muscles in the hand that lie on the anterior aspect of the metacarpals. They are smaller than the dorsal interossei of the hand, which lie between the metacarpals. Each palmar interosseous muscle arises from the entire length of the metacarpal bone of one finger, and is inserted into the side of the base of the proximal phalanx and extensor expansion of the extensor digitorum tendon to the same finger. The palmar interossei are unipennate.

From this account it may be seen that each finger is provided with two interossei, with the exception of the little finger, in which the abductor digiti minimi muscle takes the place of one of the pair.

Some texts consider the medial head of the flexor pollicis brevis to be a palmar interosseous muscle. This muscle would then be considered the first palmar interosseous muscle, and the total number of palmar interosseous muscles in the hand would be four. The palmar interosseous muscles adduct the fingers towards the middle finger. This is in contrast to the dorsal interossei, which abduct the fingers away from the middle finger. In addition (like dorsal interossei) they flex the finger at the metacarpo-phalangeal joint and extend the finger at the interphalangeal joint and thus assist the lumbricals. Wikipedia.org

<sup>iii</sup> The lumbricals are intrinsic muscles in the fingers that flex the metacarpophalangeal joints and extend the interphalangeal joints. There are four of these small, worm-like muscles on each hand. These muscles are unusual in that they do not attach to bone. Instead they attach proximally to the tendons of flexor digitorum profundus and distally to the extensor expansions. The first and second lumbricals (i.e. the two that are most lateral (the two on the radial side)) are innervated by the median nerve. The third and fourth lumbricals (i.e. the most medial two) are innervated by the deep branch of the ulnar nerve. There are four separate sources of blood supply for these muscles: the superficial palmar arch, the common palmar digital artery, the deep palmar arch, and the dorsal digital artery. The lumbrical muscles, with the help of the interosseous muscles, simultaneously flex the metacarpophalangeal joints while extending both interphalangeal joints of the digit on which it inserts. The lumbricals are used during an upstroke in writing. Wikipedia.org

<sup>iv</sup> Some researchers challenge the established view that the Dvorak layout is ergonomically superior to the QWERTY one, and hold that QWERTY emerged through a quite rigorous process of competition and eventual acceptance in the marketplace.[6]

In 1984, the Dvorak layout had an estimated 100,000 users.[7] Wikipedia.org

<sup>v</sup> The original QWERTY keyboard suffers from many problems that Dr. Dvorak himself identified:

Many common letter combinations require awkward finger motions.

Many common letter combinations are typed with the same finger.

Many common letter combinations require a finger to jump over the home row.

Many common letter combinations are typed with one hand while the other sits idle.

Most typing is done with the left hand, which for most people is the weaker hand.

Many common letter combinations are typed by adjacent fingers, which is slower than using other fingers.

About 30% of typing is done on the lower row, which is the slowest and most difficult row to reach.[3] About 52% of keyboard strokes are done in the top row, requiring the fingers to travel away from the home row most of time. Wikipedia.org

<sup>vi</sup> Wikipedia describes as follows; The Dvorak Simplified Keyboard (pronounced /'dvɔːræk/) is a keyboard layout patented in 1936 by Dr. August Dvorak and his brother-in-law, Dr. William Dealey. Over the years several slight variations were designed by the team led by Dvorak or by ANSI. These variations have been collectively or individually also called the Simplified Keyboard or American Simplified Keyboard but they all have come to be commonly known as the Dvorak keyboard or Dvorak layout. Dvorak proponents claim the Dvorak layout uses less finger motion, increases typing rate, and reduces errors compared to the de facto keyboard standard QWERTY.<sup>[citation needed]</sup> This reduction in finger distance traveled was originally purported to permit faster rates of typing, but in later years is also purported to reduce repetitive-strain injuries, including carpal tunnel syndrome.<sup>[citation needed]</sup>

Although the Dvorak Simplified Keyboard (“DSK”) has failed to displace the QWERTY keyboard, it has become easier to access in the computer age, being included with all major operating systems (such as Microsoft Windows, Mac OS X, GNU+Linux and BSD) in addition to the standard QWERTY layout. Most major operating systems have the option of toggling to the Dvorak layout.[1] It is also supported at the hardware level by some high-end ergonomic keyboards. Dvorak studied letter frequencies and the physiology of people’s hands and created a layout to alleviate the problems he identified with the QWERTY layout. The layout he created adheres to these principles:

Letters should be typed by alternating between hands (which makes typing more rhythmic, increases speed, reduces error, and reduces fatigue).

For maximum speed and efficiency, the most common letters and digraphs should be the easiest to type. This means that they should be on the home row, which is where the fingers rest, and under the strongest fingers (Thus, about 70% of keyboard strokes on the Dvorak Simplified Keyboard are done on the home row).

The least common letters should be on the bottom row, which is the hardest row to reach.

The right hand should do more of the typing, because most people are right-handed.

Digraphs should not be typed with adjacent fingers.

Stroking should generally move from the edges of the board to the middle. An observation of this principle is that, for many people, when tapping fingers on a table, it is easier going from little finger to index than vice versa. This motion on a keyboard is called inboard stroke flow.[5]

The Dvorak layout is intended for the English language. In other European languages, letter frequencies, letter sequences, and digraphs differ from English. Also, many languages have letters that do not occur in English. For non-English use, these differences lessen the supposed advantages of the original Dvorak keyboard. However, the Dvorak principles have been applied to the design of keyboards for these other languages.

The layout was completed in 1932 and was granted U.S. Patent 2,040,248 in 1936. The American National Standards Institute (ANSI) designated the Dvorak keyboard as an alternative standard keyboard layout in 1982; the standard is X3.207:1991 (previously X4.22-1983), “Alternate Keyboard Arrangement for Alphanumeric Machines”. The original ANSI Dvorak layout was available as a factory-supplied option on the original IBM Selectric typewriter. Wikipedia.org

<sup>vii</sup> Centers for Medicare & Medicaid Services Internet-Only Manual 100-8 Program Integrity Manual, Chapter 13, Section 13.7.1.