Headache and Decompression Sickness: Type I or Type II?

Major L. Michelle Bryce DO, MTM&H
Colonel William P. Butler MD, MTM&H
USAF School of Aerospace Medicine
Building 775
2602 West Gate Road
Brooks AFB, TX 78235-5252, USA

Hollis King DO, PhD
Osteopathic Manipulative Medicine
Western University of Health Sciences
309 E. 2nd St.
Pomona, CA 91766, USA

Colonel (retired) E. George Wolf MD, MPH
Larry Krock PhD
Davis Hyperbaric Laboratory
USAFSAM/FEH
2602 West Gate Road
Brooks AFB, TX 78235, USA

Andrew A. Pilmanis PhD
Air Force Research Laboratory
2504 Gillingham Drive, Suite 25
Brooks AFB, TX 78235, USA

Decompression Sickness (DCS) results from exposure to reduced environmental pressure. As a result, excess nitrogen evolves from tissues. This gas may then form bubbles that may localize in tissue or vessels. They then create symptoms that range from mild to severe. Commonly, mild symptoms are joint pains and are called Type I DCS. Severe symptoms can run a range of neurological manifestations and are called Type II DCS. Treatment for Type I may only require ground level oxygen, while Type II necessitates recompression with 100% oxygen (7).

Headache associated with DCS is not new. Ryles and Pilmanis reported an eleven-year period from the Armstrong Laboratory at Brooks Air Force Base, Texas. Out of 447 subjects, 0.9% reported headache (14). The German Air Force experience during World War II reported a 2.0% incidence rate (3). Bason searched the US Navy in-flight and altitude chamber experience. His incidence rates were 6.7% and 8.6% respectively (1,2).

The basis for this paper stems from two cases seen in the Davis Hyperbaric Laboratory and Air Force Research Laboratory at Brooks Air Force Base, Texas. This then prompted a review of headache DCS in the USAF. The traditional view has always been that a headache associated with DCS must be serious, Type II, or neurologic DCS. Yet in many cases there is no associated neurological symptoms. This begs the question, should headache always be considered Type II DCS? This paper will propose an alternative view.

Case 1

A twenty-one year old female was an altitude research protocol subject. She received no oxygen pre-breathe and subsequently went to 22,500 feet on 100% oxygen. She then developed an occipital headache at 135 minutes into the protocol. On return to ground level, she was nauseous with mild tenderness over the occipital suture. Her detailed neurological exam was normal. Recompression with 100% oxygen produced relief within fifteen minutes. Follow up revealed no recurrence.

Case 2

A twenty-seven year old female was an altitude research protocol subject. Her altitude chamber flight to 35,000 was uneventful. Nine hours later she developed a left lateral orbital headache. She did not present for evaluation and the next morning awakened symptom free. She then participated in another chamber flight to 43,000. Two hours later she developed the same left orbital headache. On evaluation she had mild discomfort to palpation over the left orbit yet no sinus tenderness. A detailed neurological exam was normal. She was given 100% oxygen, without recompression, and experienced relief in 45 minutes. Follow up revealed no recurrence.

Both cases pose an intriguing question. Should headache always be considered Type II DCS? DCS has a wide range of symptoms. This makes it difficult to diagnose and frequently can result in un-

Paper presented at the RTO HFM Symposium on "Operational Medical Issues in Hypo- and Hyperbaric Conditions", held in Toronto, Canada, 16-19 October 2000, and published in RTO MP-062.

necessary grounding of a pilot. The traditional view has always been to classify headache as neurologic and hence Type II or serious DCS. Yet many cases, like these two, have no associated neurological symptoms. An alternative explanation is proposed for headache DCS. The skull has many suture joints. Bubbles within these sutures can cause headaches. Hence, some headaches can be considered joint pain or Type I DCS.

This prompted the current study. Thirteen years of headache in the USAF were reviewed and categorized for the years 1987-1999. Retrospectively, an attempt was made to identify and classify each case into Type I and Type II DCS. Perhaps the view of sutures as joints would re-classify some cases from Type II into Type I DCS. This paper provides these results along with the supporting basis for this alternative view.

The background for this paper is based on orthodontic and osteopathic medicine. For years craniofacial remodeling has relied on suture mobility. In fact, orthodontic remodeling capability during adulthood stems from the fact that the fronto-zygomatic suture persists as a functional articulation until late in life (6). Also for the past one hundred years, Osteopathic Medicine has regarded craniofacial sutures as joints. In fact, during cranial-sacral treatment, these sutures are actually manipulated or moved. The traditional view is that sutures are fused; they are not joints. An alternative view is that sutures are <u>not</u> fused--they are joints. Hence, a DCS headache can be joint DCS or Type I DCS. This contrasts with the traditional view that a DCS headache must be neurologic or Type II.

Literature Review

In order to understand this alternative view, it's essential to look at the anatomy and physiology of sutures. Numerous studies have explored the question of suture fusion. Upledger and Retzlaff examined cadavers (n=17) between the ages of 7-78 years and ten squirrel monkeys. Gross and microscopic evaluation revealed the sutures remained clearly identifiable structures without evidence of ossification (13). Kokich examined 61 human cadavers of age 20-95 years. The purpose was to evaluate changes in ossification at five-year intervals. This is important in orthodontics. It was essential to know at what age suture remodeling is no longer possible due to fusion. Extensive examination of the fronto-zygomatic suture was done by histological, radiological, and gross dissection techniques. Kokich found no synostosis (histologic changes that ultimately lead to fusion) until very late in adult life. In fact, there was no evidence of complete fusion until age 95! He concluded orthodontic remodeling was possible throughout adulthood since the fronto-zygomatic suture persists as a functional articulation until late in life (6).

Sutures are morphologically variable with different amounts of interdigitation. Jaslow wanted to know if sections of skull with sutures have different mechanical properties than adjacent sections without sutures. Also, he was wondered if these properties varied with different amounts of inter-digitation. In goats, he looked at the bending strength and impact energy absorption of sutures versus the surrounding cranial bones. He found sutures were not as strong as bone in bending. However, sutures were able to absorb 16-100% more energy per unit volume during impact loading than bone. This demonstrates the utility of patent sutures in adults as important shock absorbers (4).

The histology of sutures reflects the function -- a firm bond of union between two bones, yet allowing a little movement. At all ages, this motion is ensured by two uniting layers that adjoin the bones and five intervening layers (the sutural ligament) that allow movement (9). (See figure 1) The uniting layer is actually two layers of fibrous tissue, an external and internal layer. The five layers of the sutural ligament include two layers of fibrous capsule, two layers of cambial tissue, and a central zone of connective tissue that contains nerves and blood vessels (9). Essentially, this sutural ligament is periosteum and a matrix of very vascular connective tissue composed of collagenous, reticular, and elastic fibers (11).

It is important to understand that the developing skull contains both sutures and synchondroses. This distinction has histological importance. Synchondroses have cartilage interposed between the bony surfaces. In contrast, sutures have well vascularized, dense, fibrous connective tissue, segmented into distinct layers. Synchrondoses will show evidence of fusion by CT scan (8). In sutures, synostosis is prevented by the non-osteogenic nature of the central part that limits bone growth (9).

Sutures have four articular patterns that result in different types of movement. The plane suture has bony surfaces that abut one another. The squamous suture has beveled bone surfaces that overlap. Both of these types permit sliding and separation. Serrate sutures have saw-toothed edges where the bones meet. Denticulate sutures have teethlike bony projections that interlock with adjacent bone. Both these types allow for slight flexion (12).

Numerous studies have been done to evaluate suture motion. Squirrel monkey studies demonstrated suture movement as measured by force displacement transducers attached to the mid-point of the parietal bones. This movement was found to be associated with respiratory and cardiac activity. (See figure 2) Flexion and extension of the spine caused the parietal bones to move relative to the spinal movement. (See figure 3) It is suspected this movement is caused by changes in the cerebrospinal fluid pressure. Additionally, there was motion independent of respiratory or cardiac activity (10). (See figure 2)

If sutures may be considered as joints, then a slightly different approach to potential DCS patients with a headache may be followed. A detailed neurologic exam must be done to rule out a neurologic component. The differential diagnosis may include sinus block, pain from an oxygen mask or helmet, and dehydration. Additionally it is necessary to localize the pain, if possible, to a suture. What is produced is a potential criteria for Type I instead of Type II DCS. This includes no clear alternative diagnosis, a localized headache along the suture, and no nerologic findings. With this understanding of sutures as joints, it seemed reasonable that some DCS headaches could be considered joint pain of Type I DCS. This prompted a look at thirteen years of headache DCS in the USAF.

Materials and Methods

The research records maintained at the Davis Hyperbaric Laboratory (USAF School of Aerospace Medicine, Brooks AFB, Texas) were reviewed. By regulation, all cases of decompression sickness (DCS) treated with hyperbaric therapy are reported to the Davis Hyperbaric Laboratory. These reports consist of Air Force Form 1352 (Hyperbaric Patient Information and Therapy Record), Air Force Form 361 (Chamber Reactor/Treatment Report), and Standard Form 502 (Medical Record---Narrative Summary). In addition, other information sources include in-patient, transfer, and aeromedical summaries.

A list of DCS victims was generated from the laboratory's database. This list included every treatment case reported to the laboratory from 1 January 1987 to 31 December 1999. Each record was then individually recovered and information extracted using a detailed two-page survey. The records were found in three formats: scanned onto a CD-ROM (1987-1990), scanned onto Canonfile diskettes (1991-1994), and hard-copy paper (1995-1999). Tracking record numbers, patient names, and birth-dates proved inconsistent. As a result, every record within the laboratory database was examined and cross-referenced to the computer listing. Interestingly, the earlier records closely matched the computer listing; however, the later records did not come close. By individually examining each database record a significant number of cases (not on the computer listing) were discovered. Although missed records are not likely, it is possible.

Once a record was accessed, it was extracted onto the two-page survey. Here, demographic information, exposure data, predisposing factors, symptom onset, symptoms and signs, diagnosis, disease progression, treatment and outcome data, and complications were recorded. No identifying personal information was obtained.

A total of 729 records documenting treatment for decompression illness were scrutinized. Of these, nineteen proved not to have DCS. Another seven did not have enough information to be of any value. Twenty had arterial gas embolism and 203 were diving DCS. The remaining 480 cases were altitude decompression sickness. Of these, the seventy cases of DCS associated with headache were examined for this report.

Results

A retrospective review of seventy cases was performed. Normally headache associated with DCS is considered Type II DCS. Recall the original seventy cases would be considered Type II DCS. Additionally, recall the prospective criteria included no clear alternative diagnosis, localized headache along a suture, and no neurologic findings. The retrospective data made it impossible to rule out an alternative diagnosis. So, this one criteria was substituted with rapid resolution of symptoms within thirty minutes of recompression treatment. Using the three criteria, sixteen cases or 23% might be considered Type I DCS. Because of the limitations of retrospective data, the criteria was loosened to only include the headache cases with a negative neurologic exam. The cases that met the criteria that could be classified as Type I were 63% or 44 cases!

Discussion

Having established that sutures are joints, DCS headaches may be considered joint pain. However, it is imperative that a thorough history be obtained to rule out other causes of headache. The differential diagnosis may include sinus block, pain from an oxygen mask or helmet, and dehydration. Additionally, a detailed neurological exam must be done to rule out a neurological component. The physical exam should confirm that the headache is localized to a suture. This suggests potential criteria for categorizing headache as Type I instead of Type II DCS. These criteria include no clear alternative diagnosis, no neurological findings, and a headache localized to a suture.

Recent stroke studies demonstrate the use of neurologic damage markers to aid in diagnosis. It is possible that these markers may be sensitive enough to help confirm true neurological DCS from joint pain. Use of neurological damage markers combined with physical exam findings of headache localized to a suture suggests a method to confirm this alternative view.

This retrospective study certainly cannot validate this alternative view. However, it does strongly suggest a prospective study be done. Acquisition of detailed data would include the three criteria: no alternative diagnosis, a headache localized to a suture, and a negative neurologic exam. Additionally, recent stroke studies demonstrate the use of neurologic damage markers to aid in diagnosis of various neurologic emergencies. These markers, specifically neuron specific enolase and tau protein are released from dying and ischemic neurons into the CSF. Crossing the blood brain barrier, they can be measured in the serum. (5) The use of neuron specific damage markers combined with this criteria suggests a method to confirm this alternative view. Additionally, a marker to identify neurologic DCS might be confirmed.

The aeromedical implications of Type I versus Type II DCS can be very different. In the USAF and the US Army, Type I DCS requires grounding for 72 hours. Type II DCS without residual signs and symptoms additionally requires a normal neurology consultation before returning to flying status. The USN is more restrictive. Type I DCS is grounded for one week. Type II DCS is grounded for one month followed by waiver action considered on a case by case basis. The FAA grounds both Type I and Type II until cleared by a qualified medical official.

Many military theaters today are remotely located. Type II DCS requires recompression treatment and a neurologic consultation before being returned to flight status. If cases could safely be classified as Type I instead of Type II DCS, this simplifies the process. Return to duty would be accelerated--essential in today's military operations.

In conclusion, the problem is due to an exposure to reduced ambient pressure. A headache develops that is localized without associated neurological findings. Our question is, must this always be considered Type II DCS or can it be considered Type I? The answer depends on following a traditional or a newer alternative view of headache DCS. The traditional view states the skull is without joints; hence bubbles causing a headache must be neurologic DCS, Type II, or serious DCS. The alternative view suggests the skull has many suture joints; thus, bubbles causing a headache may be joint DCS, Type non-serious DCS or I!

References

1. Bason R. Inflight decompression sickness: USN experience 1969-1989. In: Pilmanis AA (ed.) Hypobaric Decompression Sickness. AsMA/UHMS Publication; 1992; 389-394.
2. Bason R. Altitude chamber decompression sickness: USN experience 1981-1988. In: Pilmanis AA (ed.) Hypobaric Decompression Sickness. AsMA/UHMS Publication; 1992; 395-416.
3. Hornberger W. Decompression sickness. In: ________. German Aviation Medicine in WW II (Volume I). Department of the Air Force; 1950; 354-394.
4. Jaslow CR. Mechanical properties of cranial sutures. *Journal of Biomechanics* 1990; 23(4):313-321.
5. Jauch EC. Serum markers for acute neurologic conditions. *Audio-Digest Emergency Medicine* 2000; 17(9):1-4.
6. Kokich VG. Age changes in human frontozygomatic sutures from 20-95 years. *American Journal of Orthodontics* 1976; 69(4):411-430.
7. Krause KM and Pilmanis AA. The effect of ground level oxygen treatment for altitude decompression sickness in human research subjects. *Aviation, Space, and Environmental Medicine* 2000; 71(2):115-118.

8. Madeline LA and Elster AD. Suture closure in the human chondrocranium: CT assessment. *Radiology* 1995; 196:747-756.
9. Pritchard JJ, Scott JH, Girgis FG. The structure and development of cranial and facial sutures. *Journal of Anatomy* 1956; 90:73-86.
10. Retzlaff E, Michael D, Roppel R. Cranial bone mobility. *JAOA* 1975; 74:869-873.
11. Retzlaff E. Anatomy and physiology of craniosacral mechanisms. In: Retzlaff E and Mitchell Jr. F. (eds.) The Cranium and Its Sutures. New York: Springer-Verlag; 1987; 5-12.
12. Retzlaff E, Mitchell Jr. F, Upledger J, Biggert T. Sutural collagenous bundles and their innervation in *Saimiri sciureus*. *Anatomical Record* 1977; 187:692.
13. Retzlaff E, Upledger J, Mitchell Jr. F, Walsh J. Aging of cranial sutures in humans. *Anatomical Record* 1979; 193:663.
14. Ryles MT and Pilmanis AA. Initial signs and symptoms of altitude decompression sickness. *Aviation, Space and Environmental Medicine 1996; 67:983-989.*

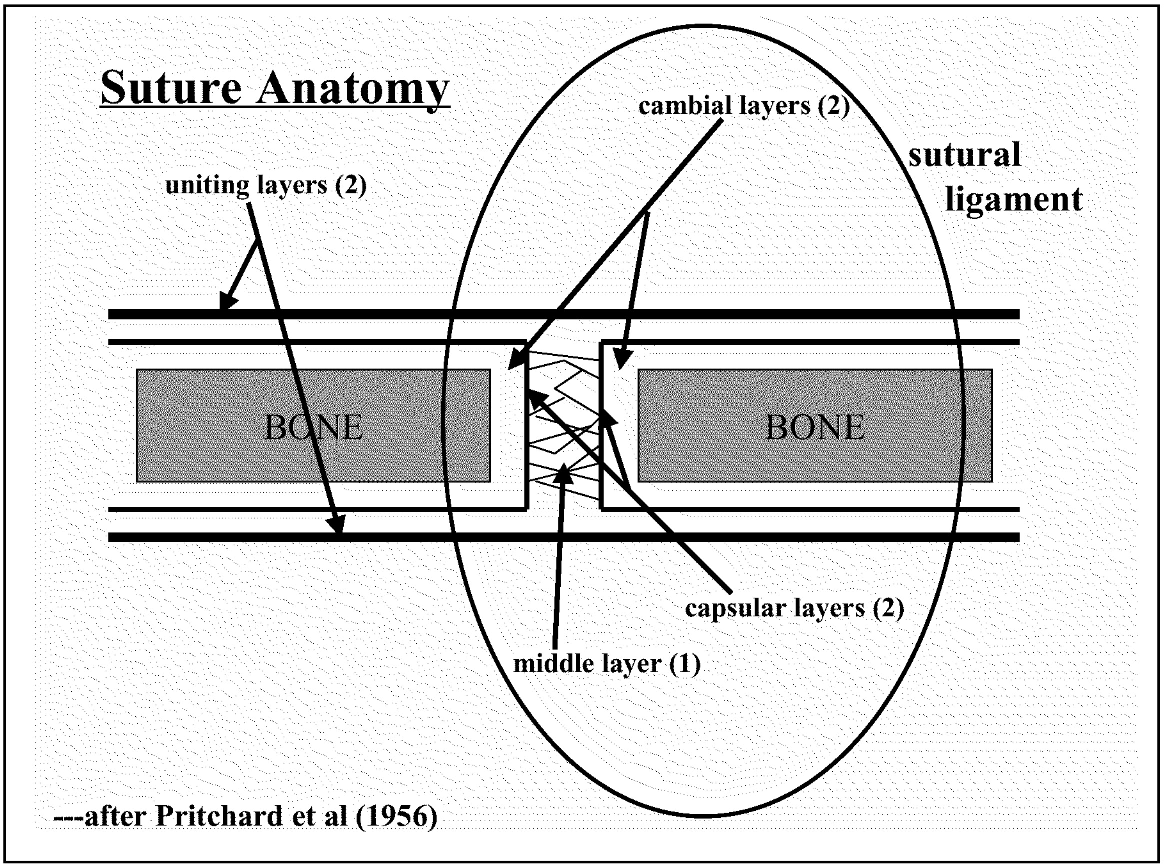

Figure 1. Sutural Anatomy

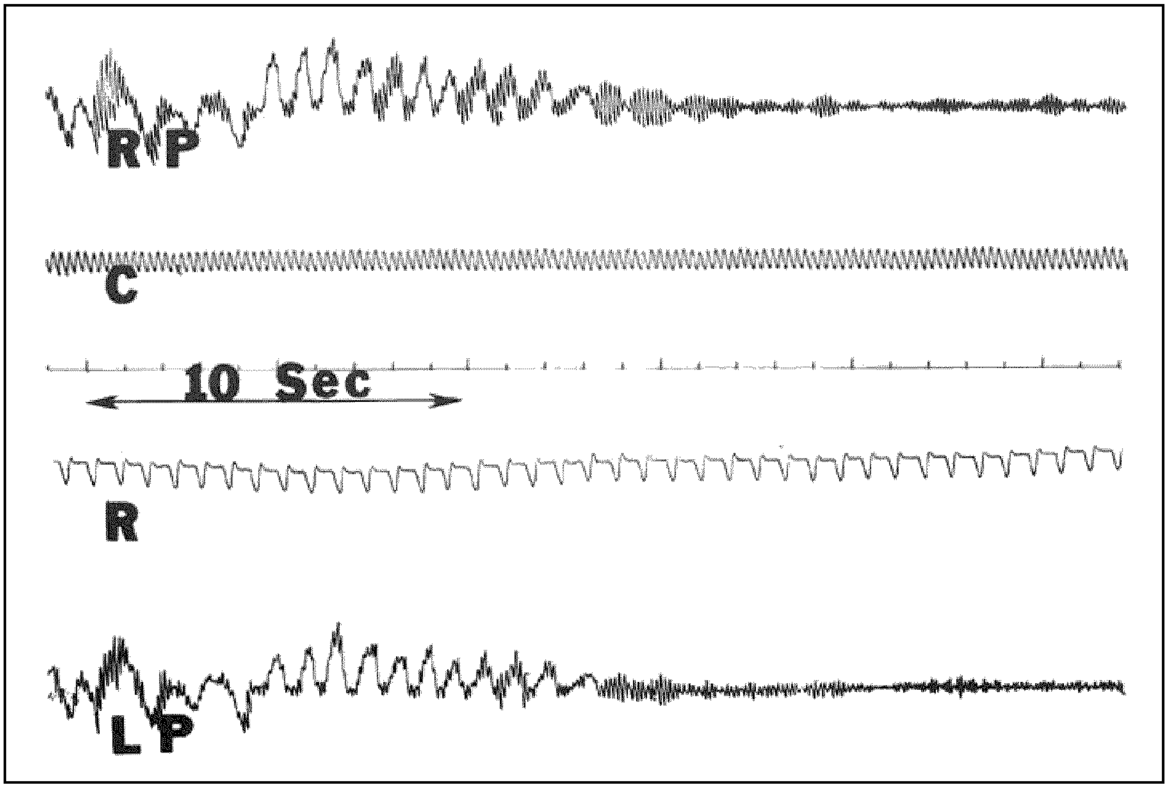

Figure 2. Sutural Movement with Spinal Flexion/Extension
Note the large oscillating waves associated with spinal flexion/extension ("RP" = right parietal bone motion and "LP" = left parietal bone motion). Also, note the rhythm patterns associated with cardiac ("C")and respiratory ("R") activity. Used with permission from *The Journal of the American Osteopathic Association*.

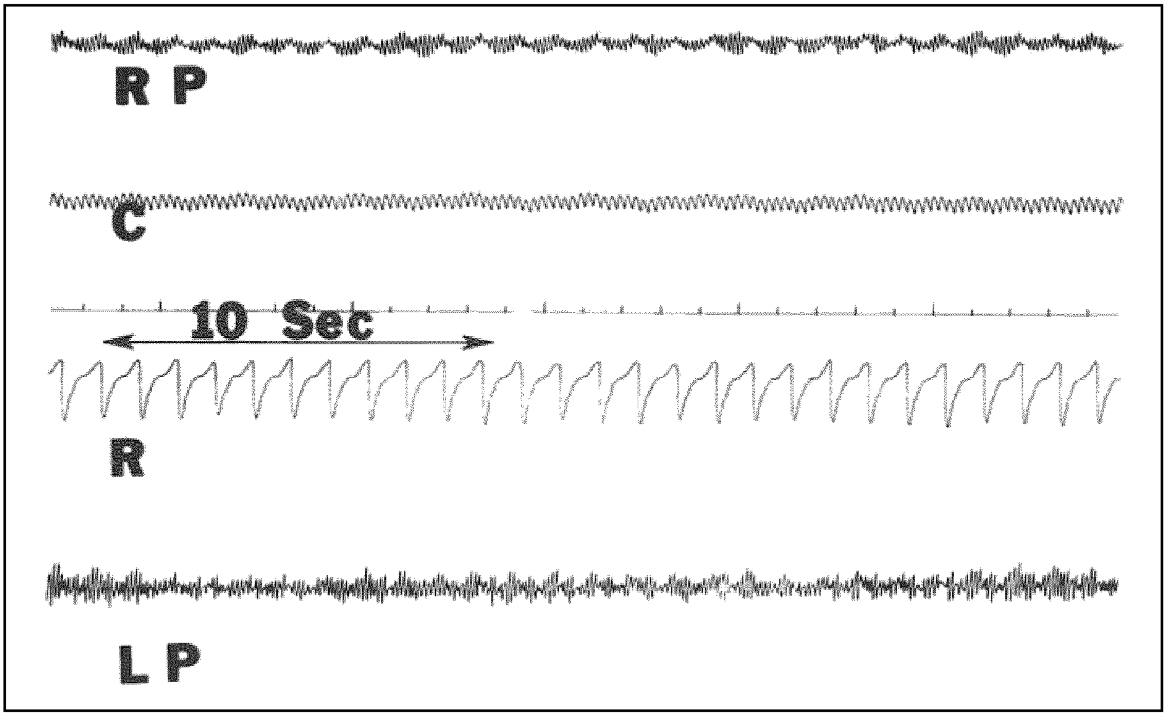

Figure 3. Sutural Movement with Cardiac and Respiratory Motion
Note the small oscillatory movement waves (cardiac) that superimpose on larger less frequent oscillatory waves (respiratory) ("RP" = right parietal bone motion and "LP" = left parietal bone motion). Also, note the rhythm patterns associated with cardiac ("C") and respiratory ("R") activity. Used with permission from *The Journal of the American Osteopathic Association*.