EFFECTS

OF

Increased Atmospheric Pressure

UPON THE HUMAN BODY:

With a Report of Thirty-five Cases brought to City Hospital from the Caisson of the St. Louis and Illinois Bridge.

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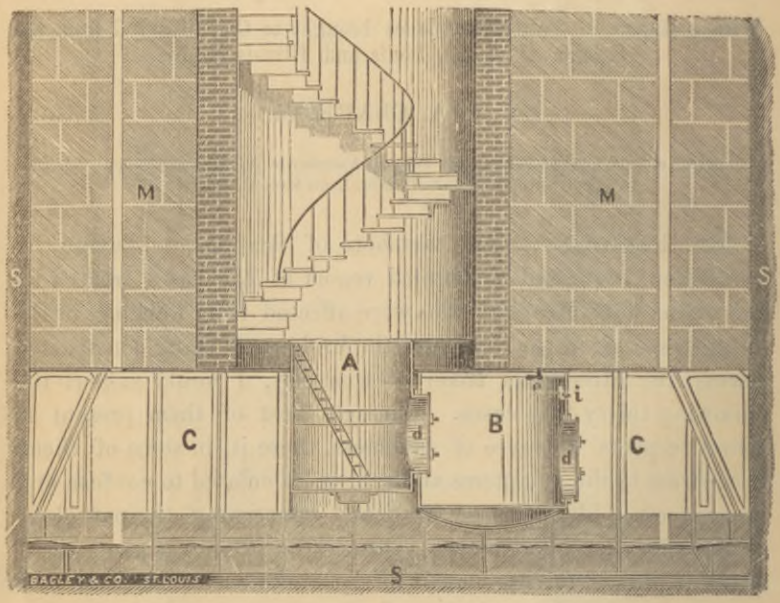
[Published by request of the St. Louis Medical Society.]

MR. PRESIDENT:—The members of this Society having, by resolution, requested a detailed report of the cases treated by me at the City Hospital, who were affected from working in the compressed air in the caisson of the bridge now being constructed across the Mississippi River at this city, I would submit the following thirty-five cases. Though most of them present in many respects a degree of sameness, there is, in some of them, a contrast in the symptoms and results, calculated to confuse any pre-conceived idea we may have had concerning the pathology of the affection. But before venturing to present these cases I think it proper, for the benefit of those who are not familiar with it, to give a brief description of the manner in which the piers are constructed, and the caisson entered at the bridge, which I have illustrated by the wood-cut on the following page, showing a section of the pier with its shaft, and caisson at the bottom.

The caisson, C C, upon which the solid masonry M M rests, is octagonal in shape, 80 feet long, 45 feet wide, and 9 feet high, constructed of heavy boiler iron, like a large box with an open bottom. This caisson, like an immense diving bell, is sunk to the bottom of the river with its open part down. Once rest-

ing upon the sand, S, at the bottom of the river, air is forced into the caisson by means of pumps, until the atmospheric pressure is sufficient to resist the pressure of the entire volume of water in the river surrounding the caisson, so as to prevent the water entering it at the bottom, where it rests upon the sand; while the compressed air also subserves another purpose, that of assisting to support the column of masonry resting upon the top of the caisson. The amount of atmospheric pressure required



for these purposes, varies at different times,—always increasing, of course, as the work on the masonry progresses—but increased or diminished according to the depth of water in the river which has to be resisted. At the time the workmen were most affected, the caisson was resting upon the rock at a depth of 95 feet, the pressure averaging from forty-five to fifty pounds to the square inch. It is in this compressed atmosphere that the workmen have to labor at digging up the sand and "puddling" it preparatory to pumping it out by large sand pumps, thus allowing the

caisson to sink in the sand as the weight of stone is increased upon the top of the pier, which is always above the water. Through the centre of the pier there is an open shaft 10 feet in diameter, with a circular stairway, A, landing at the bottom of the caisson, which is entered through the air lock, B, which is an iron box 6 feet square, in the following manner: on reaching the bottom of the stairway, the air lock is entered through the small door, d, which opens inwards. This door is then closed and the air forced into the lock through the air valve at i, until the pressure is equal to that in the caisson, when the door, d, communicating between it and the air lock swings open, while the entire pressure is then bearing upon the first door entering the air lock. The manner of coming out is just the reverse of this; on entering the air-lock from the caisson the door communicating between them is closed from without and the air allowed to escape from the "lock" through the valve at e, until the pressure is reduced to that of the common atmosphere, when the outside door is opened.

While passing through the air-lock, which requires about five minutes, persons complain of but little inconvenience, except the unpleasant ringing in the ears from the increased pressure upon the tympanis. This, however, subsides when the pressure has become equalized, and with but few exceptions the workmen suffer no unpleasant sensations during the two hours they remain in the caisson, but after entering the open air they are attacked in from five minutes to twelve hours with the symptoms detailed in the following cases, for the compiling of which I am indebted to my assistant, Dr. T. A. Arnold:

CASE I.

William C., aged thirty-six years, nativity Ireland, was admitted to the hospital, February 15th, 1870. He was a remarkably strong and robust man and had labored two hours in the caisson of the bridge.

Symptoms. — Immediately on leaving the air-chamber, he was seized with excruciating pain in the head, chest and extremities, and with hæmoptysis. No paralysis.

Treatment and results.— Chloroform was administered by inhalation and per mouth. Towels also, were saturated with it and applied to the spine. This treatment gave perfect but only temporary relief,—and was followed by full doses of morphia.

Feb. 16. The patient was comparatively comfortable, though suffering some pain in the shoulders and lower extremities. The morphia was continued and he slowly improved, and, March 23, 1870, was discharged well.

CASE II.

Charles G., aged twenty-five years, nativity United States, was admitted to hospital February 21st, 1870. He was received directly from the caisson, in which he had labored only two hours.

Symptoms.—He stated that on leaving the air-chamber at 4 o'clock, P. M., he began to feel a dull aching sensation in the joints of both the upper and lower extremities, which increased in severity until his arrival at the hospital, at 7 o'clock, P. M., when he suffered the most excruciating pain. That of the upper extremities seemed confined principally to the shoulders, while that of the lower extremities traversed the whole course of the limbs, and was described by the patient as "a grinding pain in the bones." No paralysis.

Treatment.—Hydrate of chloral, gr. xv., was given every half hour, and after the third dose was administered the patient slept soundly till twelve o'clock at night, when he again complained of pain and was again relieved by the administration of gr. xv. of the hydrate of chloral.

Feb. 22. Was still suffering from pain in both the upper and lower extremities, though much less severely than he had the evening before. The hydrate was again administered, followed with opium, gr. j., every two hours, which rendered him comparatively comfortable.

The opium treatment was continued till the 8th of March, when he was able to walk about the ward, suffering only occasional pains in the joints of the lower extremities.

March 14. Had entirely recovered and was discharged.

CASE III.

Joseph O., aged twenty-five years, nativity Ireland, was admitted to hospital, February 21st, 1870.

Symptoms. — He stated that he had worked in the bridge only two hours; and that on going down the only disagreeable symptom experienced was that of slight pain in the ears. Immediately after coming into the open air, he was seized with intense pain in the right leg and arm, and in the lumbar region. He soon became paralyzed in the lower extremities, including the bladder and sphincter ani. When he arrived at the hospital he was in a semi-conscious condition with perfect paralysis and anæsthesia of the lower extremities. Did not complain of pain.

Treatment. — A purgative was first given, followed by potass. brom., gr. xv., every two hours.

Feb. 23d. Had recovered consciousness; had very little pain.

26th. Sensation returning; some blood in urine.

27th. Sensation still improving; urine still bloody.

March 1st. Sensation was pretty good, though he was unable to distinguish a pinch from the touch of the finger.

March 2d. Had marked hyperæsthesia; thought that every object that touched him was the prick of a pin.

March 5th. Very little hyperæsthesia; was able to move his feet slightly; had entire control over bladder and sphincter ani. All treatment was suspended.

March 12th. He has constantly, though slowly improved, and is now in the hospital, able to walk about the house without assistance.

CASE IV.

George G., aged thirty years, nativity Germany, was admitted to hospital, February 27th, 1870, after having worked two hours in the caisson.

Symptoms. — On coming out he was at once attacked with severe pain in the lower extremities, which was soon converted into a dull aching sensation along the whole course of the limbs. When he arrived at the hospital was suffering very little pain, but had perfect paraplegia, including the bladder and sphincter

ani. Had some pain of a migratory character, confined almost exclusively to the joints of the lowre extremities.

Treatment.—The galvanic battery had been perseveringly applied before he left the bridge, without benefit, and on arrival at the hospital cups were applied along the whole course of the spine, but no change of symptoms followed.

March 1st. All the previous symptoms existing together, with partial anæsthesia of lower extremities.

March 11th. Complained of pain in the hypogastric region, and on introducing the catheter drew off a thick mucilaginous material with a small quantity of bloody urine. Warm fomentations with medium doses of opium soon relieved these symptoms; the paralysis of the bladder and sphincter ani disappeared and the patient seemed much better.

April 1st. Had contracted severe bed-sores, and was furnished with a water bed, which made him comfortable. There was then not much change in his symptoms, till May 1st, when he complained of intense pain over the whole of the abdomen, which was only partially relieved by warm fomentations and the administration of opium. From this time he declined rapidly and died May 8th, 1870.

It should have been stated in this case, that during most of the time his lower extremities were so completely paralyzed, and the hyperæsthæsia so intense, that even exposing his body to a slight current of air would cause him sévere pain and involuntary movements in his paralyzed extremities.

The post mortem,—revealed extensive lesion of almost every organ in his body. The brain was very much softened, and there was an extensive deposit of pus beneath the arachnoid covering almost the whole surface of the brain; the arachnoid and dura mater were so completely adherent that they could not be separated, and there was a considerable amount of exudation between the dura mater and the cranium. The dura mater of the cord was very much thickened and opaque, while instead of the spinal fluid, we found nothing but a serous pus. The substance of the cord itself was softened to almost a pulp to as high as the fifth cervical vertebra. The walls of the bladder were

immensely thickened, while at the same time softened and saturated with extravasated blood. The mucous membrane of the bladder was partly denuded and in a gangrenous condition. The whole of the peritoneum had been involved in inflammation and its surfaces extensively agglutinated together. There was also inflammation of the bowels, with gangrene of the rectum. The kidneys were considerably enlarged, and contained several small abscesses, both in their cortical and medullary substances. The spleen was enlarged to three times its normal size, and very much softened. The liver was also excessively congested and enlarged. The lungs were not so materially affected, though somewhat congested, most of which was hypostatic and *post mortem*.

CASE V.

O. L., aged 28 years, nativity Germany, was admitted to the hospital Feb. 28, after working four hours in the caisson.

Symptoms. After the first term of two hours felt slight pain in the joints of the lower extremities, but after resting two hours felt much better and returned to the caisson, and again performed two hours labor. On coming out the second time he was seized with violent pain in both the upper and lower extremities, with a sense of constriction about the chest. Soon after this he had considerable hæmoptysis, which continued at variable intervals for several days.

Treatment. — Full doses of opium were administered to subdue the pain.

March 1. All hæmorrhage had ceased, and the patient complained very little of pain. He recovered rapidly, and was discharged March 8.

CASE VI.

J. T., aged 51 years, nativity United States, was admitted March 7, after working two hours at the bridge.

Symptoms. — On coming into the open air he was attacked with violent pain in the extremities. When he arrived at the hospital he had very little pain, but perfect paraplegia, extending to the bladder and rectum.

Treatment.—The treatment consisted of free purgation, followed by liberal doses of opium to relieve pain.

March 12. Had some power of motion in the lower extremities. No pain; all treatment suspended. He gradually recovered, and was discharged March 23.

CASE VII.

Wm. Mc., aged 26 years, nativity United States, was admitted to the hospital March 7, after working in the caisson two terms, of two hours each.

Symptoms.—Had very severe pain on emerging from bridge the second time, principally confined to lower extremities; also slight headache and was very dull and stupid in his expression.

Treatment.—His pain was entirely relieved by the hot bath, 110°F. This was followed by full doses of opium. He improved rapidly, and was discharged, well, March 22.

CASE VIII.

T. H., aged 30 years, nativity England, was admitted March 8, 1870.

Symptoms.—He had been in the caisson but two hours, and on leaving it was attacked with severe pain in both the upper and lower extremities, soon followed by partial paraplegia.

Treatment.—Though suffering with intense pain on his arrival at the hospital, was relieved instantly by the hot bath, 110°F. So great was the relief that he fell asleep in the bath tub. He did not complain of pain for five hours after taking the bath, when a second bath was given him, followed with opium.

March 15. Could move his limbs freely but yet unable to walk; slight hyperæsthesia noticeable.

March 20. Could walk about the ward. After this, recovered rapidly, and was discharged March 28, 1870.

CASE IX.

C. P., aged 22 years, nativity England, was admitted March 19, 1870. His stay in the caisson had been only two hours.

Symptoms. In a few minutes after leaving the air-chamber was seized with excruciating pain in both the upper and lower extremities. No paralysis.

Treatment.—He received the hot bath—110° F., and was immediately relieved. The pain partially returned in six hours, when the hot bath was repeated and followed by the administration of opium, which procured comparative comfort. Under this treatment he rapidly improved, and was discharged, well, March 21, 1870.

CASE X.

J. S., aged 22 years, nativity Germany, was admitted March 10, after working two hours in the bridge.

Symptoms.—Very severe pain in the lower extremities, and also in the shoulders. In a few hours paraplegia occurred, with marked mitigation of pain. The paralysis extended to all the interior organs of the body, the bladder and sphincter ani. On catheterizing, the bladder was found filled with almost pure blood, and this condition continued for several days.

Treatment.—His pain was quite relieved by the hot bath, so much so that he slept in the water; but perfect paralysis and anæsthesia of the lower extremities continued unimproved.

March 18. Complained of great pain over different portions of the body. No appetite; is quite feeble. Alcoholic stimulants, and a nutritious diet were ordered, but he sank rapidly, and died March 22.

Post Mortem. — The brain and spinal cord were found highly congested, the latter being softened in many places into a pulpy consistency. There was evident subarachnoid effusion and probably more than a normal quantity in the dura mater of the cord. Small drops of extravasated blood were found at different points on the external surface of the latter membrane. All of the abdominal viscera were surcharged with blood; the lungs suffering less in this respect than any of the other organs. There were clots of extravasated blood found in both kidneys; one of the ureters was very much enlarged. The mucous membrane of the bladder was thickened and presented the appearance in many places of ecchymosis, which condition was continuous along the whole course of the urethra. The bladder contained a small amount of bloody urine.

CASE XI.

U. A., aged 36 years, nativity Germany, was admitted March 11, 1870. He had labored in the caisson two terms of two hours each.

Symptoms.—After coming out the second time was seized with severe pain in the entire right side, most severely in the shoulder and elbow. Sensation in this side was very much impaired, with entire paralysis of the arm and partial paralysis of the leg; left side normal. Treatment, none.

March 13. Sensation and motion improving.

March 15. Hyperæsthesia of right side, power of motion greatly improved.

March 17. Had entirely recovered and was discharged.

CASE XII.

J. L., aged 25 years, was admitted to hospital May 13, 1870. Had worked in the bridge caisson several days, and on coming out the last time, about a week previous to his admission, was attacked with the usual symptoms—severe pain in the extremities, followed by partial paraplegia. When he came to the hospital was having pains of a migratory character in different parts of the body, but was able to walk. He was soon after attacked with pneumonia, which was combatted with the usual remedies. He made a slow recovery and was discharged, cured, May 10, 1870.

CASE XIII.

D. A., aged 32 years, nativity Scotland, was admitted to hospital, May 13, 1870. He had worked at the bridge eight days, and on coming out the last time, just before his admission, was attacked with violent pain in both knees, which was soon succeeded by a feeling of numbness and partial paralysis of the lower extremities, including the bladder and sphincter ani.

Treatment.—Warm baths were given twice, daily.

March 16. Patient much better, and the baths were discontinued.

March 18. Had transient pains in different parts of the body, but was able to walk with a cane.

March 24. Was attacked with inflammatory rheumatism which was treated with opium and potash, and on April 11, 1870, was discharged.

CASE XIV.

J. M., aged 35 years, was admitted March 14, 1870. A few hours before admission had visited the caisson, where he remained two hours.

Symptoms. — On coming out he had suddenly lost the power of motion of both upper and lower extremities, but felt no pain at that time. A few hours after admission he recovered the use of his arms and could move the legs slightly.

Treatment. — Hot baths, followed with opium. General hyperæsthesia ensued.

March 16. All pain and hyperæsthesia had disappeared. Urine bloody, with a fœtid, disagreeable odor.

March 17. Urine still bloody, and patient quite feeble, from which time he sank rapidly and died on the 19th.

Post Mortem. — The brain and spinal cord, including the meninges, were found highly congested, with marked subarachnoid effusion. The substance of the cord was slightly softened in the lower portion of the dorsal region, and the veins in this portion of the cord were thrombosed. Small clots of extravasated blood were found on the external surface of the dura mater in both the cervical and dorsal regions. The thoracic and abdominal viscera were found highly congested; the lungs being much less so than any of the other organs. Clots of extravasated blood were found in the left kidney. The bladder contained a small quantity of bloody urine. The mucous membrane of that organ was thickened, and presented the same ecchymosed patches described in case No. ix.

CASE XV.

Wm. T., aged 27 years, was admitted March 16. He had worked two hours in the caisson, the depth of which, at that time, was ninety-five feet below the surface of the water.

Symptoms. — On leaving the air chamber he was siezed with intense pain in the joints of the lower extremities. The pain was

soon succeeded by paralysis of the lower extremities, including the bladder and sphincter ani. After the paralysis occurred there was very little pain.

Treatment. — Warm baths, with opium, constituted the whole treatment.

March 20. The paralysis was disappearing, and he had marked hyperæsthesia. He improved rapidly, and March 25, was discharged, well.

CASE XVI.

R. H., aged 40 years, nativity United States, was admitted to hospital March 16, after having labored two hours in the caisson.

Symptoms. — At first, severe pains in both the upper and lower extremities, followed in a few hours by paralysis of lower extremities with marked mitigation of the pain.

Treatment. — The treatment consisted wholly of the warm bath, followed by opium. The bath had the usual effect of instantly quieting the pain.

March 21. Recovering the use of his limbs; marked hyperæsthesia of the whole body, which, however, subsided in forty hours, after which he recovered rapidly, and was discharged March 29.

CASE XVII.

C. B., aged 30 years, was admitted to the hospital, March 16. He had labored in the caisson only two hours.

Symptoms. — He had the tympanic membrane of both ears ruptured while at work in the chamber; had very little pain at any time, but was partially paralyzed in the lower extremities. Without treatment he gradually improved both in his hearing and motion, and March 25, was transferred to Quarantine.

CASE XVIII.

J. R., aged 21 years, was admitted March 17. Had worked two hours.

Symptoms. — On coming out into the open air he was seized with severe pains in the legs and shoulders, with a frequent desire to micturate. No paralysis.

Treatment. — Opiates and diuretics were administered, which soon relieved all his symptoms, and he was discharged, well, March 22.

CASE XIX.

Wm. Mc., aged 30 years, was admitted March 19. He had worked in the caisson three months and occasionally felt slight pain in the joints of the extremities, but they had never been sufficiently severe to prevent his working, until the last time he came out of the air chamber, which was three weeks previous to his admission. On that occasion he had no pain, but immediate paralysis. Could walk when admitted, and rapidly recovered without treatment, and was discharged March 26.

CASE XX.

John Wagner, aged 32 years, was admitted March 17. He worked in the bridge two terms, of two hours each, on the day of admission, and on coming out the last time was suddenly attacked with severe pain; first in the arms and shoulders, and soon after in the lower extremities. The pain continued very violent for several hours, when paraplegia occurred, involving the bladder and sphincter ani, with marked mitigation of the pain.

Treatment. — He received none at first, but after a few days opium was required to relieve the pain, which, by this time, had returned.

March 25. No pain; could move his feet very little. He had, after this date, no continued pain, but often had severe pain of a migratory or transient character, which was always relieved by opium.

April 1. Had a violent diarrhœa, which was promptly checked by astringents.

May 15. Is still in the hospital with no important change in his symptoms. Is still paralyzed in lower extremities, and occasionally suffers severe pain in different portions of the body.

June 23, died. Up to time of death his mind was perfectly clear.

Post Mortem. — In this case the brain only was examined,

which was found to be extremely anæmic and somewhat softened, especially the cerebellum, which was quite pulpy; the arachnoid membrane was quite opaque and slightly adherent to the sub stance of the brain. The veins of the brain were entirely emp tied of blood, and the ventricles contained no fluid.

CASE XXI.

G. S., aged 22 years, nativity France, was admitted to hospital March 20, after working two hours in caisson.

Symptoms. — Fifteen minutes after leaving the chamber had very severe pain in both the upper and lower extremities, which continued unmitigated in intensity until his admission, a few hours subsequent to his attack. No paralysis.

Treatment. — Cups were applied along the whole length of the spine and about ℥iv of blood thus taken. This was followed by the application of an ice bag to the spine, which gave him relief from pain and caused him to sleep soundly all night.

March 21. Was much better, though the pain was not entirely relieved.

March 22. Was able to walk about the ward, after which he rapidly recovered and was discharged on the 28th.

CASE XXII.

C. B., aged 26 years, nativity Germany, was admitted March 21, after two hours labor in the caisson.

Symptoms. — On coming into the open air had violent pain in the joints of both upper and lower extremities, and marked hyperæsthesia. No paralysis.

Treatment. — A hot bath—110°—was administered, and followed by full doses of opium.

March 23. No pain; treatment discontinued.

April 1. Some pain in feet, which was relieved with opium.

April 3. Had a sensation of itching over the whole body.

April 5. Had entirely recovered, and was discharged.

CASE XXIII.

T. B., aged 21 years, was admitted March 21, in an unconscious condition, with a low muttering delirium. He was not paralyzed, but seemed to suffer considerable pain, which was re-

lieved by the hot bath—110°. The patient never became conscious, but died, comatose, March 23.

Post Mortem. — The brain and spinal cord, together with their investing membranes, were found highly congested, with effusion of serum under both the arachnoid and dura mater. There was also slight inflammatory adhesions between these two membranes. The abdominal viscera were all highly congested, while the lungs were almost normal. The pericardium contained greatly more than its normal quantity of serum. Some small clots of extravasated blood were found on the external surface of the dura mater of the cord. The kidneys were highly congested, and the bladder contained a small amount of bloody urine.

CASE XXIV.

B. B., aged 28 years, was admitted March 22. He had worked in the employ of the Bridge Company two days, the first of which he worked only two hours; but on the second day worked six consecutive hours, and on leaving the caisson had violent pain in both extremities which was followed, in a few hours, with paraplegia and retention of urine.

Treatment. — The hot bath, followed with purgatives and opium. Was discharged, well, April 11.

CASE XXV.

Pat H., aged 34 years, nativity Ireland, was admitted March 22. He had worked two terms of two hours each.

Symptoms. — On leaving the caisson the last time, had excruciating pain in both the upper and lower extremities. No paralysis.

Treatment. — Warm baths were first given, and followed with full doses of opium. He rapidly recovered, and was discharged March 28.

CASE XXVI.

C. B., aged 24 years, had worked in the bridge two terms of two hours each, and was admitted to the hospital March 22.

Symptoms. — Severe pains in the joints of both upper and lower extremities, with a feeling of constriction about the chest.

No paralysis. He was brought to the hospital a few hours after the attack, in a semi-conscious condition.

Treatment. — A warm bath was first given, which gave prompt relief to his pain; afterwards dry cups were applied to the spine, with apparent benefit. In a few hours after the administration of the bath the pain began to return and was subdued by full doses of opium.

March 25. Was entirely conscious, and complained very little of pain, from which time he recovered speedily, and was discharged April 5.

CASE XXVII.

N. P., aged 23 years, nativity Germany, had worked in the caisson two hours on the day of his admission to the hospital, March 24.

Symptoms. — On coming into the open air felt severe pains in the arms, which soon extended to the lower extremities, and was followed, in a few hours, with paralysis of the lower extremities, the bladder and spincter ani.

Treatment. — The galvanic battery had been freely applied at the bridge with only temporary relief. When received at the hospital a warm bath, 110°, was administered, followed by full doses of opium.

March 25. Very little pain; treatment suspended.

March 28. Much better; had very little pain; the paralysis was disappearing. Some hyperæsthesia. Was taken home by his friends.

CASE XXVIII.

Wm. P., aged 24 years, was admitted March 24. He had worked in the bridge two hours.

Symptoms. — Half an hour after coming out had nausea and difficulty of breathing; fifteen minutes later, severe pains in the shoulders and lower extremities, without paralysis.

Treatment.—The hot bath was administered, and gave immediate relief; but the pain returned, though less severe, in six hours. A second bath was given, followed with full doses of opium, after which he recovered rapidly, and was discharged March 28.

CASE XXIX.

M. L., aged 37 years, had worked in the caisson four consecutive hours on the day of his admission, March 25.

Symptoms. — Two hours after leaving the air chamber he was attacked with severe pains in both the upper and lower extremities. Although there was no actual paralysis the pain was so severe as to prevent his walking or standing.

Treatment. — The hot bath was administered once a day for a week, when the patient had so far recovered as to be able to walk. Treatment then entirely suspended and he was discharged well, April 10.

CASE XXX.

H. S., aged 20 years, was admitted March 27. He had worked in the caisson several days without inconvenience, and on coming out the last (18th) time, was instantly seized with violent pain in the lower extremities, with partial paralysis of the left leg.

Treatment. — A warm bath was given him on his arrival at the hospital, which relieved his pain and diminished the paralysis. In a few hours, however, the pain partially returned and was relieved by the administration of opium.

March 30. Had very little pain; no paralysis; some hyperæsthæsia of the lower extremities. He made a speedy recovery and was discharged April 4.

CASE XXXI.

E. K., aged 27 years, had worked in the caisson three months without inconvenience until the day of his admission, March 27.

Symptoms. — Shortly after coming out the last time the lower limbs became quite cold and paralyzed without pain. When he arrived at the hospital there was partial anæsthesia and for a short time unconsciousness.

Treatment. — Warm baths twice daily.

March 30. The paralysis began to disappear; and severe pain ensued, which was subdued by full doses of opium.

April 1. No paralysis, and but very little pain. Slight hy-

peræsthæsia. He improved rapidly from that time, and was discharged, April 10, well.

CASE XXXII.

C. C., aged 24 years, was admitted to the hospital, March 29, 1870. He had on the day of his admission worked in the caisson six hours, that is three terms of two hours each, having rested, as is their custom, two hours between each term of labor.

Symptoms. — On coming up the last time, was seized with severe pain in both the lower and upper extremities. The pain was so severe as prevent his walking or standing. No paralysis.

Treatment. — He received a hot bath, 110°, which gave him such marked relief that he slept in the bath tub. This was followed by the administration of opium, which prevented a return of the pain. He recovered rapidly and was discharged April 5.

CASE XXXIII.

J. B., aged 22 years, had worked only two hours in the caisson, on the day of admission, April 1.

Symptoms. — Excruciating pain in both upper and lower extremities, followed by paraplegia, including the bladder and sphincter ani. Continued headache with perfect anæsthesia of the lower extremities.

Treatment. — The warm bath relieved the pain only temporarily and was followed by the administration of opium.

April 5. Complained of great pain over the region of the bladder and on catheterizing drew off a quantity of almost pure blood. The pain was partially relieved by warm fomentations.

April 6. Still had bloody urine with pain in the hypogastrium. Treatment continued with only partial relief.

April 12. Was taken suddenly with severe pain over the whole abdomen, which was tympanic and very tender on pressure. Opium and warm fomentations were given without relief.

He sank rapidly, and after intense suffering died on April 30.

Post Mortem. — The brain and its meninges were found highly congested with subarachnoid effusion and probably more than a normal quantity of serum in the dura mater of the cord.

The cord was decidedly softened in the lower dorsal region. There were also small clots of extravasated blood on the external surface of the cord. The viscera generally were found congested, except the lungs, which seemed entirely exempt from this lesion. The mucous membrane of bladder was greatly thickened and extensively ulcerated. One of the ulcers had perforated the bladder, allowing its contents to flow into the cavity of the peritoneum, which gave rise to violent peritonitis, of which abundant evidence was found. The intestines were extensively adherent to the peritoneum and to each other. The lower portion of the colon, and the rectum, were in a gangrenous condition and were easily torn. The kidneys were intensely congested and contained clots of extravasated blood.

CASE XXXIV.

M. R., aged 31, had worked in the caisson two terms of two hours each on the day of admittance to hospital, April 1.

Symptoms.—On coming out the second time had violent pain in the lower extremities. No paralysis.

Treatment.—The warm bath was given with immediate relief, after which opium was freely administered to prevent its return.

April 10. Patient was able to walk about the ward.

April 15. Was discharged well.

CASE XXXV.

D. B., aged 24 years, was admitted April 22. He had worked in the caisson five days. The last time had worked four consecutive hours and on coming out was attacked for the first time with pain in the head, back and shoulders. He was treated at his boarding house for three weeks, after which he came to the hospital, having almost recovered. He received no treatment. Was discharged well April 26.

Prof. Paul F. Eve has kindly presented me the history of three cases which came under his observation, which I add here as given in his own language:

Louis B., aged 21, came under my observation February 26, 1870. I found him suffering the most intense agony of pain I have ever witnessed, from the hip joint down to the foot. With-

out a moment's delay I gave him a hypodermic injection of sulphate of morphia (gr. ¼), and the same amount immediately afterwards, internally. He experienced almost instant relief.

Upon inquiry I found him to be one of the victims from working in the caisson of confined air, in the erection of the piers of the bridge across the Mississippi river. Taking full notes of case, they read thus: Commenced work in the caisson some time during the month of November, 1869, and worked constantly up to the time of the present attack. About six weeks after commencing work he felt some stiffness in the knees and hips, which continued up to February 26, 1870, the beginning of the present attack. About Christmas week he had a severe hemorrhage from the nose, on leaving the confined air, preceded by a violent attack of pain across the frontal bone, just above the eye-brows, which was instantly relieved by the bleeding. Had another bleeding at the nose just two weeks before the present attack. Experienced a dry cough during the time he worked in the confined air. Two days before the present attack he had urticaria over the whole surface of the body. While the eruption was upon the surface he felt perfectly well, but immediately upon its disappearance he was attacked with violent pain in the right leg, from the hip down, almost producing convulsions, which continued about an hour. He was then carried to his house. On the way from the bridge he was violently attacked again, during which attack I was called to see him. I found him suffering intensely in the lower extremity, and in the right upper extremity, between the elbow and shoulder joints. Had violent muscular contraction in both extremities upon the right side of the body, also twitching of the muscles of the face and tongue.

February 26. Pulse about eighty beats to the minute; tongue clean, bowels regular, appetite good, which have continued the same up to this time, March 7. As a regular course of treatment, placed him upon bromide of potassium—10 grains every two hours—with an anodyne of 30 drops of laudanum at night. Continued this treatment up to March 4, without any perceptible effect. I then determined to try Dr. S. B. Smith's

electro-magnetic machine, which I did with the most happy result. I placed the positive pole of the battery over the lumbo-sacral region, while the negative pole was passed rapidly over the extremity. I have continued this once a day up to the present date, March 7. My patient to-day is walking around without any inconvenience, except a slight pain in the right knee.

March 12. Patient perfectly well; improved rapidly under the use of the battery.

Mike Mahoney, aged 21, commenced work in the caisson between the middle and last of January, 1870; worked about four days before feeling any symptoms of pain whatever. At the expiration of that time the first symptoms experienced were stiffness and pain in the joints alternately, the right leg, from the hip down, being paralyzed (sensation alone, motion being unimpaired) for about an hour and a half, the severe pain in the joints continuing. He then ceased to work for about ten days. At the end of that time he resumed it again, entirely free from any symptoms; but upon entering the caisson, and remaining two hours, then coming to the open air, he felt again violent pain in the upper and lower extremities, which continued during the time he was in the open air (two hours). Descending again in the caisson, on reaching the confined air he was entirely relieved. Worked for two hours, and again ascended to the open air, when he was attacked more violently than before. In addition to the pain in the extremities, he had a burning, suffocating sensation in the chest, with paralysis of sensation alone of the left side of the face and tongue, which lasted about an hour and a half, but the pain in the extremities continuing about twenty hours. Being somewhat relieved at the end of that time, he again resumed work (the caisson being just four feet from the west bed), and remained down for two hours, and came out without any additional suffering. Remained out two hours, then went down again and remained two hours; came up again and sat by the stove, when he felt intense pain again in the joints alternately, and violent pain in the epigastrium, at the center of which there was a red spot about the size of half a

dollar; the suffocating pain in the chest continuing more violently than before, with paralysis of sensation of the whole body, from the neck down. He was then carried to his home. On the way he had violent vomiting twice. The paralysis of the body lasted about five hours; he then began to get better, the pains gradually leaving him, but extreme dizziness, or vertigo, all the time, which has continued up to date, March 8, 1870.

John C., aged 43, about the middle of January, 1870, commenced work in the caisson, and worked only four hours; came out to the open air feeling perfectly well. On his way home, just entering Broadway, he was violently attacked with pain in both knees, not feeling any symptoms elsewhere. He received no treatment, except his physician gave him a liniment of some kind to rub upon his knees. The pain in his knees continued up to date, March 7. I tried to persuade him to allow me to apply the battery, but he would not.

PATHOLOGY.

While reviewing these cases in search of the real pathological conditions to account for the symptoms presented, we are not at so much of a loss as to account for the peculiar manner in which these conditions are produced as a result of exposure to a compressed atmosphere, which in itself does not seem to differ from common air, so far as its immediate effect upon the individual exposed is concerned. But remembering the well marked pathological conditions revealed in the *post mortems* upon these cases, there cannot be any doubt as to the exact nature of the lesion, which consists, first, in a congestion of all the viscera of the body, with the exception, probably, of the lungs, which, however, do not entirely escape in all cases. Following this primary condition we have all the sequelæ of an active congestion, such as effusion, inflammation and destructive disintegration of the tissues involved. This excessive congestion of all the interior organs of the body would seem to point to some cause operating upon the surface, producing a retrocession of blood from the superficial vessels; but while we believe that the primary cause

operates upon the surface of the body, we also admit that after this condition has existed for a certain length of time the brain and nerve centers become exhausted, and powerless to resist the mechanical forces operating upon the circulation. By this we mean the increased atmospheric pressure upon the surface of the body, which being more than three times that of the atmospheric air, must necessarily compress the superficial vessels, and force the blood in upon the interior organs of the body, where such pressure cannot be equalized in a compressed atmosphere, except in the lungs, which being exposed alike with the surface of the body, are found the least affected; indeed, in many cases they do not seem to be at all congested, while other organs not so exposed are entirely disorganized. This is especially true of the brain and spinal cord, which being contained in a bony cavity cannot, of course, be affected by a counter pressure, or have much space in which to yield to the increased amount of blood forced upon them, and are consequently the first to be affected, as is evinced by the first symptom of pain, paralysis or numbness, which is invariably present in every case when first attacked. Judging from the constancy of these symptoms in all the cases that have come under my observation in the hospital, and from the fact that some of the workingmen have been affected in this manner while they were still in the caisson, we infer that the same condition exists, to a greater or less degree, in all persons who are exposed to this increased atmospheric pressure. In some, however, it is so slight as not to be observed in the individual himself, while many others, amongst whom visitors who enter the caisson for the first time, are more or less affected with symptoms of vertigo, muscular weakness, and occasional pains in the lower extremities. All these symptoms, varied so much in their intensity, lead us to infer that those who suffer but slightly still possess the power of reaction, and do not succumb to the increased atmospheric pressure so much as those who seem to be more susceptible to its influence, and are exhausted beyond the power of reaction when they enter the open air, so that they remain in the same condition—that is, congestion of all the abdominal viscera, brain and spinal

cord—until the most vital of these organs become exhausted, and paralysis, especially of motion, ensues. The efforts at reaction, even in these extreme cases, during the entire course of their sickness, seems to be expended upon the sensory nerves and arteries, causing the well marked hyperæsthesia which occurs in so many cases, and, in many instances, is so acute as to cause automatic, or involuntary, movements in the paralyzed extremities, from the reflex action of the hypersensitive afferent nerves, (which are so sensitive as to be influenced by the friction of a feather upon the skin, or a sudden current of ordinary atmospheric air); the reflex action being so excessive in some cases as to excite severe pain in the lower extremities, which, when undisturbed, were entirely insensible, and their motive power beyond the control of the patient. Yet, with all this hyperæsthesia, there seemed to be a want of intelligence in the sense of touch, that is, the patients could never determine from what cause they suffered pain, when it was inflicted upon them by artificial means. For instance, when they were blindfold, and any irritation made upon the skin, they could not determine whether they were being burned, scratched, pricked or pinched, and the movements made under such influences did not seem to be controlled by any power of coördination; and even many cases that had been paralyzed, in making their first efforts to walk, did not seem to possess the powers of coördination of motion, and were affected like a persons uffering from locomotor ataxia. While guided by the sense of sight they seemed to suffer but little inconvenience in walking, but when the eyes were bandaged they were unable even to stand erect, much less to walk.

As to the peculiar manner in which this increased atmospheric pressure produces such a condition, or why persons are so generally not affected until they come out to the open air, is a question not easily reconciled in the minds of many who have had an opportunity to observe the phenomena. Some persons, as stated, have been affected in this manner while remaining in the caisson, where the pressure was so excessive as to induce such a congestion of the brain and spinal cord, that these centres became exhausted under the immediate influence of the pressure,

just as in the case of those who are not affected until after they enter the open air, when the period of attack varies from a few minutes—as has been true in but a few cases—to twenty-four hours after they leave the air-chamber.

Inasmuch, then, as some have yielded to the influence of this pressure while still under its immediate influence, it might reasonably be inferred that some of those who are not so affected until several hours after they leave the caisson, might have succumbed in the same manner, had they remained in the air-chamber during the entire time from the period of their entering until the time they were attacked, for it is apparent in those cases that are attacked after they enter the open air, that in consequence of the continued great pressure upon the surface of the body, the nerve centers have become exhausted from the excessive congestion, not only of these organs but of all the abdominal viscera, (some of which are next in vitality to the brain itself), so that the patient is unable to react even under the most favorable circumstances. That this is true, is demonstrated by the clinical appearance of the patients.

When first attacked—and until reaction is established—the surface of the body is cool, the face pallid, the pulse increased in frequency and diminished in fullness, indeed presenting all the appearance of collapse, more or less complete, and as a further indication that these conditions depend upon congestion of of the interior organs of the body, it is invariably true, in every case, that where the proper remedies have been used to attract the circulation to the surface of the body—such for instance as the hot bath at a temperature of 110°—the immediate effect is to relieve the patient and arrest his pain so long as the reaction can be maintained by such means. Then certainly all these phenomena cannot be caused from excessive reaction induced by passing from the compressed to the open air, as has been asserted by some who have attempted thus to account for all the results occurring in these cases.

It has been asserted also, that this congestion of the viscera of the body does not occur in consequence of the increased atmospheric pressure upon its surface, for the reason that the pres-

sure is equalized throughout the cavities of the body, and consequently influences the circulation as much in the interior organs as upon the surface of the body. This theory cannot certainly be sustained by any process of reasoning, for we know that it is not true of an individual living in the common atmosphere, except so far as the exposure of the lungs is concerned. Certainly we cannot say that the force of the circulation is resisted by atmospheric pressure in the cavities of the cranium and vertebral canal, neither can we say with much more propriety that the same condition exists in the cavities of the abdomen and chest.

But it may be suggested as an analogy in these cases, that if it were not for this equalization of pressure in the interior of the body, that the ordinary atmospheric air would produce the same results as the compressed atmosphere not equalized. But this analogy cannot explain the results derived from the two conditions. In the case of atmospheric air, where there is but fifteen pounds to the square inch exerted, this is just the natural force to equalize the resistance from the force of the circulation, which is probably due to two causes, the first of which is the centrifugal force of the heart's action, together with the contractibility of the blood-vessels themselves; and the other, what we may term the vital chemical affinity between the blood and the tissues.

The heart, like other central motive powers, forcing fluid at a radiation from a common centre, has a tendency to cast it in a straight line, which being interrupted by the curves and irregular course of the arteries, together with the distension of their caliber, may exert a force sufficient to resist in some degree, the pressure of the ordinary atmosphere upon the surface of the body. However, what the *modus operandi* of the centrifugal force may be to resist the pressure of the common atmosphere, does not materially interest us, inasmuch as we know it does exist, from the fact that when the atmospheric pressure is removed there follows immediate congestion of the surface of the body. But to what extent this force operates, we of course cannot accurately determine. That it cannot act as the only

balance between the circulation and the pressure of the atmosphere we may feel assured, when we recollect the chemical affinity existing between the blood and the tissues is such that the blood is attracted by this means to the most remote parts of the body, so long as this affinity exists between the blood and the tissues; that is, so long as the blood contains those chemical elements which belong to the tissues it will seek its affinity, even against a very considerable degree of atmospheric pressure, or other influences calculated to retard or repel it. This force is the more apparent from the fact that the same process still continues, really after death — or after the contractions of the heart have ceased.

We cannot account for the arteries being empty after death from the *vis a tergo* of the heart alone, neither the contractibility of the arteries themselves, but from the effect of this vital chemical affinity which has sufficient attraction to force all the blood in the arteries into the veins without the aid of the heart's action.

Then we regard these two forces, *i. e.*, the centrifugal force and the chemical affinity existing between the tissues and the blood, as sufficient to resist the pressure of the common atmosphere upon the surface of the body, and maintain an equilibrium of the circulation in the cavities of the body, where a counter pressure from the atmosphere would be impossible, as in the chest, vertebral canal and cavity of the cranium.

It has also been asserted that the peculiar symptoms incident to exposure to this compressed atmosphere are due to hyperoxidation of all the tissues of the body, resulting from the increased volume of oxygen compressed within the air chamber, which by its action causes an increased disintegration of the tissues while remaining under the influence of the compressed air, and that this disintegrated tissue accumulates to such an extent in the tissues that when the individual is admitted to the common atmosphere, where there is a less volume of oxygen, this accumulated carbonaceous disintegration cannot be eliminated rapidly enough with the comparative small supply of oxygen in the open air, so that the patient suffers, as it were, from poisoning by car-

bonic acid gas. This theory implies, of course, that while the person remains within the compressed air of the caisson the disintegration and elimination is equalized to such a degree that so long as the individual continues under these conditions he incurs no risk of an attack; but that when he enters the open air the amount of disintegrated material accumulated in the body, in consequence of the hyperoxidation of the tissues, is such that the amount of oxygen in the open air is not sufficient to eliminate it, and its effects are felt upon the constitution in the manner detailed in the above cases. Now, while we admit that the causes are obscure which affect so large a proportion of those exposed to this influence after they have entered the open air, yet when we remember that there have been persons attacked in the most severe manner while remaining in the air-chamber, and died in a few minutes, we cannot reconcile this theory as sufficient to account for the phenomena presented in the cause and effect operating upon these cases.

Again, we do not recognize as a fact, that there is an increased relative amount of oxygen consumed by the individual while breathing this compressed atmosphere, from the fact that the relative proportions of the atmosphere are identically the same as those of the common air, though contained in a smaller space; for, while there may be said to be three volumes of oxygen in one, it is proportionately diluted with its usual equivalents of nitrogen, which is subject to the same compression and reduction in volume as the oxygen. Then it does not seem possible that the blood should be surcharged with oxygen, when the air inhaled contains the same equivalents of nitrogen and oxygen as the common air, as the red corpuscles cannot absorb more than their normal portion of oxygen while the air is thus diluted. The conditions would be different upon a person being confined in an atmosphere of pure oxygen, the effects of which would be to arterialize the blood throughout the entire venous system, which does not exist in those who are affected in this compressed atmosphere. Blood drawn from patients suffering the consequences of this increased pressure presents all the appearances of venous blood.

Then again, as must be true of all chemical affinities, the re-

ciprocal action between the two elements must be mutual; if even there should be an increased proportion of oxygen in the atmosphere where the individual breathes, which would probably increase the carbonaceous disintegration of the tissues and furnish more carbonic acid to be eliminated, yet, while there is an excess of oxygen in the air surrounding the body, the affinity between the oxygen and carbon must be mutually equal when presented to the lungs in a free state ready for combination, so that the elimination of carbonic acid gas must exactly correspond to the amount of oxygen consumed, inasmuch as it is one of the elements of its production. Surely, the attraction of oxygen towards the carbonic acid in the lungs is as strong as that of the oxygen for the tissues where the carbon is generated; consequently the production of carbonic acid, and the elimination of carbonic acid gas, must be exactly equal when the amount of oxygen inhaled is in excess of the normal quantity. Yet we do not presume to say that an individual might live in an atmosphere of pure oxygen with impunity, even though the carbonic acid should be eliminated as rapidly as it is produced. Under such conditions the individual would certainly die from the excessive disintegration of the tissues and their waste by elimination, and not from the excess of carbon accumulated in the tissues from a want of its elimination. In fact, it has been demonstrated that in the case of animals allowed to perish from the effects of inhaling an atmosphere of *pure* oxygen, instead of the blood being surcharged with carbonic acid, it is found to be hyperoxygenated, both in the arteries and veins; that is, excessively arterial throughout the body, instead of containing an accumulated quantity of disintegrated tissue, as has been asserted to be true in the cases referred to, where it is not claimed that the excess of oxygen consumed is much more than that contained in the common atmosphere.

But whether these patients suffer from the effects of atmospheric pressure upon the surface of the body, while in the caisson, or the increased amount of oxygen in the atmosphere they breathe, it does not in either case indicate that there can occur an accumulation of carbonic acid in the body to such an extent as to destroy the life of the patient, or develop the ordinary symptoms

in those generally affected when entering the open air, as a consequence (as suggested by Dr. Hodgen) of the want of sufficient oxygen to eliminate the amount of carbonic acid accumulated in the body while under this increased pressure where the oxygen is supposed to be in excess of its proportion in the normal atmosphere. However, as a contradiction to the statement that an increased amount of oxygen may be consumed by the blood, and its products not immediately eliminated, Professor Flint, in his recent work on the "Physiology of Man," states that the proportion of oxygen which the red corpuscles are capable of containing is to a certain degree absolute, and not dependent upon physical conditions, such as pressure, which invariably have an influence on the proportion of gas merely held in solution by liquids; and that the proportion of oxygen in the blood *cannot* be increased by *pressure*, nor is it diminished by reduction of the pressure, until it approaches a vacuum.

SUMMARY.

Whole number of cases admitted to Hospital,		35
Cured,	27	
Relieved,	3	
Died,	5	35
Cases accompanied with paralysis,		19
" " hyperæsthesia,		11
" " hæmoptysis,		2