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AUTHORITY

Army Biological Defense Research Lab ltr dtd 13 Sep 1971

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TRANSLATION NO. 180

DATE: July 1968

DEPARTMENT OF THE ARMY
Fort Detrick
Frederick, Maryland

Liquor cerebrospinalis in Veterinary Medicine by R. Fankhauser

From the Department for Comparative Neurology of the Veterinary Ambulatory Clinic, Bern. Zentralblatt für Veterinärmedizin, 1953, Vol. 1, No. 2, Nov 53. (Only designated portions have been translated)

During the past 15 to 20 years the treatment of normal and morbid cerebrospinal fluid of animals has experienced a gratifying upturn, and initial foundations have been laid for comparative observation. As late as 1941 Rehm (3), one of the most prominent promoters of animal fluid research, wrote: "The literature clearly shows that a thorough and systematic study of the normal conditions of cerebrospinal fluid has not been accomplished for hardly any species of animal. Consequently "pathological" findings should be accepted and evaluated with a certain amount of caution. Doubtless the analysers have unilaterally (and one can say, with little critique) taken for granted that animal fluid is equal to human fluid in its biological properties." Although today we have advanced a step further, the knowledge in veterinary medicine of animal fluid, compared to the human, is still in its beginning. The present paper, which would stimulate further testing and reduce the unjustified reservations of most practitioners toward the extraction of cerebrospinal fluid, shall give a short compilation of current knowledge. We believe ourselves to be justified in making such a synopsis, since we can expand on and supplement the results of other researchers with experience gained by means of several hundred spinal taps of various animal species (horse, cattle, sheep, goat, swine, dog, cat, rabbit). Moreover, most of our findings, as far as they concern animals with clinical disorders, have been confirmed by later neurohistological tests, a fact that should be of considerable value, considering the current status of the problem.

We shall not consider several areas such as the historic development of cerebrospinal fluid extraction and testing, its physiology, and laboratory methods, which are extensively discussed in manuals and monographs. Neither shall we touch on bordering areas such as methods of epidural and subarachnoidal anesthesia, the introduction of drugs and X-ray contrast agents into the fluid spaces, etc.

It has proven to be sufficient to consider the following properties of cerebrospinal fluid in our tests, with an orientation that is primarily clinical and pathologic-anatomical:

Evaluation of pressure, speed of outflow, amount of fluid that flows spontaneously, transparency, color; count and differentiation of cellular elements; reaction after Nonne-Apelt, Pandy and Weichbrodt; determination of total albumin, sugar and if indicated, of chlorides; normomastix and gold sol reactions; bacteriological tests, if necessary.

While the first mentioned properties can of course be tested independently and even cell count and cell differentiation as well as the technically very simple reactions after Nonne, Pandy and Weichbrodt can be accomplished by everyone, the quantitative analysis and colloid reactions are best effected in a laboratory that has been arranged for that purpose. (Footnote: We are indebted to the Serologic Laboratory of the Psychiatric Clinic of Basel University).

All other properties of the fluid, which we also list in the following tabulations --- mostly according to tests by other writers ---, while they are very interesting scientifically, are hardly usable clinically at this time. We are utilizing the experiences of the Basel laboratory with humans in evaluating normomastix and gold sol curves, since the normal conditions

of animal fluid (with the exeption of the horse) correspond favorably with that of man. Regarding the mastix curve one can speak of a certain pathologic reaction only at the start of precipitation and in respect to the gold sol curve, not before a blue color is obtained. It is therefore superfluous to debate the importance of slight degrees of turbidity or light color changes, since this may well depend on technical differences and especially on unequal sensitiveness of the utilised colloid solutions.

HORSE

The normal cerebrospinal fluid of the horse.

Data in the following tabulation have been extracted from the work of Behrens, 1950(9), and supplemented by reports of Rehm 1942(4), and our own examinations.

Normal horse fluid is clear as water and colorless. In cell differentiation it becomes apparent that even in the normal state, beside lymphocytes there occur histiocytes in approximately like amounts. Moreover, as also reported by Rehm (4), occasionally there are seen large, pale, concentrically stratified elements whose nature has not yet been clarified. They are probably degenerate forms of some sort of cell.

	Minimum	Maximum	Medium
Pressure (lateral position)	272 mm H_2O	490 mm H_2O	379 mm H_2O
pH	7.13	7.36	7.25
Specific gravity	1004	1008	1006
Viscosity	1.0	1.05	1.0
Cells	4/3	23/3	11/
Calcium	5.55 mg%	6.98 mg%	6.2 mg%
Phosphorus (inorganic)	0.87 mg%	2.20 mg%	1.44 mg%

		Minimum	Maximum	Medium
Magnesium		1.06 mg%	2.95 mg%	1.98 mg%
Potassium		10.65 mg%	14.20 mg%	12.66 mg%
Sugar		40 mg%	78 mg%	57.2 mg%
Chlorides		690.59 mg%	792.11 mg%	737.03 mg%
Alkali reserve		41 vol.%	67 vol.%	55.6 vol.%
Residual nitrogen		13.72 mg%	39.20 mg%	26.88 mg%
Total albumin:	foals	43.75 mg%	77.0 mg%	65.64 mg%
	adults	28.75 mg%	71.75 mg%	47.58 mg%
Albumin:	foals	37.63 mg%	68.87 mg%	55.12 mg%
	adults	22.62 mg%	67.94 mg%	38.64 mg%
Globulin:	foals	3.81 mg%	20.06 mg%	10.49 mg%
	adults	3.37 mg%	18.37 mg%	9.34 mg%
Albumin quotient:	foals	0.06 mg%	0.57 mg%	0.24 mg%
	adults	0.06 mg%	0.69 mg%	0.26 mg%
Nonne-Apelt		Trace	Opalescent	Opalescent
Pandy		+	+ + +	+ +
Weichbrodt		-	-	-
Cholesterin (powder)		0.25-0.51mg%	0.48-0.65mg%	0.36-0.55mg%
Ca/P		2.49	7.92	4.64
Ca/Mg		2.02	5.42	3.28
Ca/K		0.44	0.58	0.51

The normomastix and gold sol reactions invariably show deep left or middle curves, as was also reported by Rehm, 1942(4). For this reason it is quite difficult to evaluate pathologic losses, unless they attain very considerable degrees. Tests which unfortunately have been all too small in

number, tend toward the conclusion that determination of thyrosin-albumin and biuret-albumin may attain a certain importance.

CATTLE

Normal bovine cerebrospinal fluid.

The values given in the tabulation below were obtained by the testing of 250 normal fluids. Properties not tested by us are drawn from the results of Fedorow, 1947(29) and Nawratski (cited by Roeder and Rehm 1942). Normal bovine fluid is water-clear and colorless. (Footnote: The lumbar fluid almost invariably reveals small, whitish flakes in small number; the microscope shows amorphous, acidophilic masses, probably condensed detritus of destroyed cells). Lumbar pressure stays under 200 mm H_2O; with the animal standing, the fluid normally does not flow spontaneously out of the 125 mm long, vertical needle; this is the case only on increased breathing or vigorous defensive movements. Spontaneous outflow without these two conditions points to pathologically increased pressure in the subarachnoid cavity.

Specific gravity	1005 to 1008
Viscosity	1.019 to 1.029 (Fedorow)
Surface tension	1016 to 1032 (Fedorow)
Freezing point depression	-0.54 to -0.55°C (Fedorow)
Alkali reserve	46.9 vol% (Fedorow)
Calcium	5.1 to 6.3 mg% (Fedorow)
Potassium	11.2 to 13.8 mg% (Fedorow)
Organic components	28 mg% (Nawratski)
Ash	700 mg% (Nawrątski)
Cells	0/3 to 10/3 (up to 20/3 if normal otherwise)

Total albumin		16 to 33 mg%
Globulins	Nonne-Apelt	negative to trace of opalescence
	Pandy	negative
	Ross	2-8 mg%
Globulin/albumin quotient		0.11 to 0.25
Weichbrodt		negative
Sugar		35 to 70 mg%
Blood sugar/fluid sugar		1.0 to 2.0 (very variable)
Chlorides		650 to 725 mg%

The normomastix and gold sol curves are quite similar to those of humans. Fig. 2 shows the various normal curves, which also apply to the normal cerebrospinal fluid of small domestic ruminants and swine. Günther, 1940(32) ascertained the vitamin C content in the fluid of healthy cattle and those afflicted with various non-neurologic diseases. He found slightly increased mean values (1.45 mg%) in female animals compared to males (1.005 mg%), and the highest content in healthy, pregnant cows (2.3 to 2.5 mg%). Rossi, 1939 (34), explored the urea content in the fluid of unweaned calves and found values between 4.0 and 18.0 mg%, in the majority of cases between 6.0 and 12.0 mg%.

SHEEP

Normal cerebrospinal fluid of sheep.

We reiterate here a summary of results obtained by Adamesteanu et al (39) and Bagedda (40); differences in cell number and total albumin content may be explained by the fact that Adamesteanu tested suboccipital fluid which always has higher values. Our results did not differ with the tabulation; we merely want to report that at one time a clinically healthy sheep gave us

A CELL COUNT of 60/3. The fluid of sheep is clear as water and colorless, the pressure, according to Bagedda, measures 6 to 27 (medium 13) cm H_2O in the horizontal position, 22 to 48 (medium 37) cm H_2O in the sitting position. Under favorable conditions 4 to 13 ccm fluid can be obtained.

Reaction	weakly alkaline
Cells	0 to 15/3 (small and large lymphocytes, mononuclear cells, endothelia)
Total albumin	8 to 70 mg% (medium values 29 to 42 mg%)
Nonne-Apelt	negative
Pandy	negative
Weichbrodt	negative
Sugar	48 to 1[illegible] mg% (medium 52 to 85 mg%)
Chlorides	750 to 868 (medium 832) mg%
Residual nitrogen	9.6 to 42 (medium 29) mg%
Calcium	5.77 mg%
Magnesium	2.86 mg%
Ca/Mg	2.05

Normomastix and gold sol reactions same as those of cattle and goats (Fig 2).

We could not find any data concerning the pathology of cerebrospinal fluid in sheep, and are unable to contribute anything on our own part. It would be very valuable to conduct fluid examinations in connection with a good number of this animal's diseases. We are thinking here especially of scrapie, louping-ill and swayback, all illnesses that do not occur in this country.

GOAT

Concerning the goat we merely found data by Dixon and Halliburton, 1913(41), reporting suboccipital punctures of this animal. The orientation

of this work was purely physiological, and examinations of cerebrospinal fluid apparently were not conducted. We can tentatively give the following normal values which undoubtedly can be corrected by more extensive tests:

Appearance	clear as water and colorless
Pressure	Dripping flow upon suboccipital tap in the lateral position
Amount	8 ccm in an adult animal
Cells	3/3 (small lymphocytes)
Total albumin	12 mg%
Nonne-Apelt, Pandy and Weichbrodt	negative
Sugar	71 mg%

Normomastix and gold sol reaction curves same as those of normal bovine fluid.

SWINE

The fluid properties of this animal also have been explored but little. The first scientist to publish a few test results seems to have been Lichtsteiner, 1942(43), of our own clinic. In a recently published paper Fischer and Starke, 1951 (42), report on the test results of an imposing number of normal and pathological fluids.

The authors of the present paper were also able to collect some data during the past few years.

Puncture technique.

We do not think that the extraction of cerebrospinal fluid from swine could become a method of daily practice, as would be possible with cattle, and under certain conditions, with dogs and horses. In dealing with small and medium-size swine only suboccipital taps can be considered, which will initially cause difficulties due to the low position of the membrana atlantooccipitalis, i.e. they will not always be effected without admixture

of blood. General anesthesia is indispensable with most animals. In regard to large swine of over 100 kg it is possible to obtain a few ccm of fluid by lumbar tap, as happens without specific purpose during lumbar anesthesia. However, the fluid must be aspirated with the syringe, which always increases the danger of blood admixture. In the "sitting dog" position (possibly with animals suffering from hindlimb paralysis) the tap is less difficult. The puncture must be lumbosacral, since farther cranially the dural sheath is already filled to capacity by the spinal marrow. The spot can be tolerably palpated, so that lengthy groping usually can be avoided after a certain amount of practice.

Normal cerebrospinal fluid of swine.

Appearance	water-clear, colorless
Cells	1/3 to 20/3 (even 50/3 if otherwise normal)
Total albumin	24 to 29 mg% (up to 40 mg% according to Lichtsteiner)
Globulin	5 to 10 mg%
Albumin	17 to 24 mg%
Albumin quotient	-0.49
Nonne-Apelt, Pandy, Weichbrodt	negative
Sugar	45 to 87 mg%

Normomastix and gold sol reactions: See Fig. 2.

Pathology of cerebrospinal fluid in swine.

Fischer and Starke, 1951(42), studied the fluid properties of normal piglets and of those experimentally infected with Teschen virus (polioencephalomyelitis ensootica suum). They ascertained that pleocytosis is the most constant fluid symptom in infected swine, and that its progress is parallel with the severity of clinical appearances, but often not parallel

with pathologic-histological changes. Pleocytosis usually sets in at the beginning of the paralytic stage, quickly reaches its apex, later to abate again, without reaching the norm, however. In 10% of the 78 cases tested a cell increase of between 14/3 to 100/3, or 100/3 and 500/3, was noted already in the preparalytic stage. At no time were meningeal symptoms observed clinically when cerebrospiral fluid was normal. The results are summarized as follows:

Appearance:	clear as water; slightly turbid if pleocytosis over 500/3; sometimes light fibrin "stocking".
Cells:	over 14/3 up to 3004/3, medium of these values 517/3; monomuclear cells, never polynuclear cells
Total albumin:	36 to 192 mg%, usually 36 to 67 mg%
Globulin:	9.6 to 84 mg%
Albumin:	19.2 to 108 mg%
Albumin quotient:	0.36 to 1.2
Sugar:	92 to 113 mg% (maximal 162 to 180 mg%) at the end of the preparalytic stage and the beginning of paralysis. Sometimes normal or subnorm l values
Mastix reaction:	slightly positive curves in the middle or right areas, seldom left curves.

In our cases of experimental Teschen disease with inoculation material from spontaneous cases we saw, with the exception of the colloid reactions, similar changes with pleocytosis of 48/3 to 209/3 (small and large lymphocytes, monocytic cells), total albumin values not over 50 mg% and not always positive reactions after Nonne and Pandy; the sublimate test after Weichbrodt was always negative. The sugar content did not rise beyond 98 mg%. On the other hand we saw stronger precipitation in the mastix and gold sol curves, predominantly in the left and middle regions, which correspond to the histologic findings of severe parenchymal damage with strong meningeal involvement.

Fig. 6 shows examples of such curve progressions.

We were able to observe Nonne-Froin's syndrome (obstructed fluid) in an adult boar with compression of the spinal cord due to a pyogenous abscess in the upper vertebral column:

Appearance	turbid, yellowish, coagulates after a few minutes; a fibrinous coagulum shrinks and expulses a clear, xanthochromic fluid with the following properties:
Cells	3/3 (mononuclear)
Total albumin	2500 mg%
Biuret-albumin	3440 mg%
Nonne-Apelt	++++ (coagulation)
Pandy	++++
Weichbrodt	-
Sugar	56 mg%
Colloid curves	see Fig. 7

The characteristic signs of obstructed fluid (isolated lumbar fluid that gradually is changed by transsudation from the meningeal veins), namely coagulation and a high degree of albumino-cystologic dissociation, permit the immediate diagnosis of spinal cord compression and a corresponding unfavorable prognosis.

DOG

A relatively high number of works have been devoted to the normal and pathological cerebrospinal fluid of the dog. We will not consider any publications of an experimental nature, the older of which contributed to the development of fluid physiology and which preceded the introduction of lumbar and suboccipital taps of man. According to Becht, 1920(47), Magendie had made suboccipital punctures of dogs as early as 1842!

Starting in 1925, interest was shown in some places in the veterinary-scientific aspect of the question. We cite, inchronological order, the names of Vladescu 1925(63), Aronowitsch 1926(46), Ullrich 1928(60), Vuillaume 1935(64), Pegreffi and Doria 1937(57), Constantinescu 1938(50), Nigge 1944(55), Agnet 1946(45), Legrand 1948(52), Ruso 1950(58), Rindrich and Schmidt 1952(48), and finally Verwer 1952(61), as well as Teunissen and Verwer 1953(62), the last of which recently published the most pleasing and probably most comprehensive study of the normal and pathologic fluid of the dog. As for ourselves, we have been able, during the past years, to collect 50 fluids of dogs with nervous disturbances, a modest number, but connected with the advantage of precise clinical-neurological and histo-pathclogical examinations. In order to contract the representation as much as possible, we combine our own results with those scattered throughout the literature into one overall perspective. The interested reader will easily find the contribution of each writer by means of the bibliography; it should be stressed, however, that the works of Rindrich and Schmidt and of Verwer and Teunissen are the most important to date.

Puncture technique.

Although it is possible to obtain a few drops of fluid by lumbar tap, all examiners agree that only the suboccipital puncture will furnish an amount sufficient for testing, with the necessary regularity. Anesthesia is not essential under all circumstances, but simplifies the work and reduces operational risk to a minimum. Following first trials we, too, have discontinued punctures without narcosis. The animal is advantageously placed in the lateral position, with its back to the operator, and if he is right-handed, with its head to the left. The location of injection, i.e. the

depression immediately in front of the arch of atlas (usually easily palpated), is shown and carefully disinfected. The tap can be performed with a suboccipital needle for children, another suitable model with a mandrin, or an ordinary needle with a sharp, short-filed point, not too thick and not too short. The first two have this advantage, that the fluid is not polluted with blood during passage through the muscles, the latter that fluid flows out immediately when the needle point reaches the subarachnoid cavity. It is recommended to have needles of different length and caliber, since anatomical conditions among various breeds and ages vary considerably. Brook, 1936(49), lists the depth of the membrana atlanto-occipitalis for the large breeds at 3.5 cm, the medium at 2.8 to 3.0 and the small at 1.0 to 1.5 cm. According to our experiences we would presume that the differences are considerably greater, for instance between a strongly muscular boxer and a griffon. The choice of needle length requires a certain amount of experience; in doubtful cases a longer one should be used, since nothing is more exasperating than to see a puncture seemingly fail, and to find later that one merely had not reached the membrane.

The animal's head should be at an angle of 90° to its chest, but not more, and suitable pads should be used to obtain a horizontal position of the cervical portion of the vertebral column, as otherwise the position of the membrane may shift in relation to the palpable orientation points. The needle is injected at the deepest point of the aforementioned depression in front of the arch of atlas, parallel to the long axis of the head and exactly along the median line. The penetration of the membrane is evidenced by a sudden slackening of the elastic resistance, by a short convulsion, even of a narcotised animal, and possibly by the outflow of the fluid, if an

ordinary needle is used. In rare cases excitation of short duration may set in; one should not be disturbed by it, but should hold the animal as tightly as possible, release the needle and fixate the skin at the nape of the neck, until the agitation is past. It seems to us, by the way, that a certain minimum of experience (which can be advantageously supplemented by practice on cadavers) is more valuable than too detailed rules of puncture technique, because anatomical conditions are subject to considerable variation. It is noteworthy that the arch of atlas represents a more constant orientation point than the occipital protuberance.

Even in the best technique, under some conditions a certain degree of blood admixture to the fluid is unavoidable, in that sometimes small veins of the suarachnoidal plexus are damaged. These hemorrhages are harmless to the dog; twice we saw a facial paresis, which however disappeared shortly. This is confirmed by our own observations of swine which were purposely stabbed through the medulla, as well as by aforementioned tests by Adamesteanu et al (39) with sheep.

Normal cerebrospinal fluid of the dog.

Results reported by various examiners agree on the whole, so that we can combine them in the following list. We find a certain difference in the gold sol curves between those of Verwers (61) and ours. He sees the strongest color change (up to red-violet) in the third tube, while in our test this invariably happens in the 3-5 first ones. However, these differences are without any clinical significance, and probably are caused by differing techniques and possible inequality in the utilized gold sol solutions. Our normal curves duplicate almost exactly those of Lange, as reproduced by Verwer (61) on page 85.

	Minimum	Maximum	Medium
Amount	0.9 cc	16 cc	6.5-7.0 cc
Appearance	clear, colorless; in some cases fibrin net		
Pressure	24 mm H_2O	172 mm H_2O	86.5 mm H_2O
Specific gravity	1003.3	1012.5	1005.6
Cells	0/3	25/3	6/3
animals under 7 months	4/3	24/3	14/3
according to Verwer (62) only small lymphocytes			
according to Bindrich and Schmidt (48):			
small lymphocytes	15%	95%	65%
large lymphocytes	5%	40%	21%
degenerate forms	0%	40%	14%
according to own tests, occasionally also endothelia			
Nonne-Apelt	-	(+)	-
Pandy	-	(+)	-
Weichbrodt	-	-	-
Total albumin	11 mg%	55 mg%	27.5 mg%
Globulin	5.5 mg%	16.5 mg%	9.0 mg%
Albumin	16.5 mg%	37.5 mg%	27.0 mg%
Albumin quotient	0.14	0.75	0.35
Sugar	61 mg%	116 mg%	74 mg%
Chlorides	761 mg%	383 mg%	808 mg%
Dry substance (Pegreffi and Doria (57)			12-12.75 g%
Ash (Pegreffi and Doria (57)			9.8-10 g%
Freezing point depression (Pegreffi and Doria (57)			
	-0.61°C	-0.63°C	-0.61°C

Residual nitrogen under 40 mg% (Liess)(53)

Benzoin reaction (Guillain) 0 000 000 000 000 000 to 0 000 008 644 200 000

Normomastix and gold sol reactions see Fig. 8.

The pathology of canine cerebrospinal fluid.

For the time being the more solid knowledge of pathologic canine fluid is limited almost exclusively to the inflammatory processes of the central nervous system, without however differentiating the individual forms which can already be delineated neuro-histologically. It is here especially where is shown how much work still remains in the veterinary research of cerebrospinal fluid, notwithstanding the relatively high number of papers on the dog. It is obvious that we must treat encephalitis of the dog as one single unit within the framework of this paper, and cannot discuss the much debated questions of its etiology. Since the results of the various examiners (Vladescu 63), Aranowitsch 46, Nigge 55, Legrand 52, Ruso 58, but especially Bindrich and Schmidt 48, as well as Verwer and Teunissen 61, 62) agree in the main, we shall here reproduce only the essence of their findings, whereby we can also utilise our own experience.

It has been shown that changes in the fluid do not correspond to the type and severity of clinical symptoms, but approximate the developments of the histopathologic process. In this connection it is apparent that meningeal changes have a greater effect on fluid composition than those of nervous parenchyma. This fact has no surprises for the worker whose experience covers both the clinic and the pathologic histology of diseases of the canine central nervous system. Indeed, the histologically apparent changes are usually quite minimal in the case of acute meningo-encephalitides of the dog, which are distinguished by a very impressive symptomatology.

One can speak of "serous" meningo-encephalitis; in this stage, which often is not exceeded before death occurs, the fluid properties are generally changed little or not at all.

On the other hand, the morphologically oriented analyser is not surprised to find fluid changes in animals with weak symptoms on the part of the central nervous system, because histologic tests often do not reveal expected changes, or atleast not to such a marked degree. It therefore appears to us that considering the present state of the problem, future work on cerebrospinal fluid must include pathological histlogy along with the clinical aspect.

On the basis of our own conclusions and those of other researchers, we believe that the following groups can be tentatively differentiated concerning the dog:

1. Normal fluid or only slight deviation, as pleocytosis up to ca. 30/3, posaibly lightly positive globulin reaction, mastix curves on the border of the "still normal" (maximum degree of turbidity); generally too uncertain to allow diagnostic conclusions:

Intoxications; acute serous meningo-encephalitis; tetanias; psychic disturbances of post-traumatic nature or unknown etiology; hydrocephalus congenitus; lesions only of the spinal cord, as traumas, hernia of the intervertebral disk, intraspinal tumors, or rarely isolated myelitides of lumbar marrow.

Ruso, 1950(58), mentions a pathological mastix curve that he calls "myelitis curve" and which he had observed especially in connection with "hindlimb paralysis." A neurohistological control of the material should have shown that these fluid changes are not to be ascribed to myelitis, but

to simultaneous (and clinically often difficult to find) meningo-encephalitic changes.

2. Xanthochromic and erythrocytes-containing fluid (not caused by tap pollution), total albumin 90 to 500 mg%, Nonne and Pandy strongly positive, strongly positive normomastix and gold sol reactions with a peculiar double peak that has never been seen in other groups:

Inflammatory or toxic processes with severe vascular damage and extensive meningeal hemorrhages; in one case caused by fungus poisoning.

Xanthochromia of the fluid with slight pleocytosis (53/3) and hyperproteinorhachia (42 mg%) and slightly positive Nonne and Pandy was seen in one case of toxoplasmosis-encephalitis with large necrosis foci and hemorrhages.

3. Clear or (with pleocytosis above ca. 500/3) lightly turbid fluid, occasionally with fibrin threads or white flakes; pressure within normal limits, sometimes increased; invariably pleocytosis of various degrees, that is, 30/3 to 3000/3, but usually between 50/3 and 300/3.

In dealing with experimental distemper, Bindrich and Schmidt, 1952 (48), note only small and large lymphocytes as well as degenerate forms in a medial ratio of 66.3 : 19.3 : 14.3%. However, we find, in agreement with Verwer and Teunissen, 1952, 1953 (61, 62), in connection with spontaneous, non-purulent meningo-encephalitides the following cell elements: 1. erythrocytes (with the reservation that they may have reached the fluid through puncture damage); 2. small lymphocytes and bare nuclei of same; 3. medium and large lymphocytes; 4. monomuclear cells; 5. monocytes; 6. endothelial cells; 7. plasma cells; 8. gitter cells; 9. neutrophilic granulocytes; 10. various degeneration forms. Giant cells are very rare. The major portion

of cell elements consists of lymphocytes and mononuclear cells.

Total albumin usually increases somewhat parallel to the degree of pleocytosis; generally it does not rise very high, ca. 40 to 150 mg%.

The Nonne-Apelt and Pandy reactions are usually positive, from traces to + + +, but in some cases negative. They react independently of total albumin content. Weichbrodt's test is slightly positive only in exceptional cases. The albumin quotient (globulin/albumin) fluctuates between 0.2 and 8.0 (Verwer, 61).

In most cases sugar remains within normal bounds, it may however decrease (up to 25 mg%) or increase (up to 150 mg%) occasionally.

Chlorides vary between 673 and 918 mg%, consequently exceed normal low and high values only little; Verwer (61) found a value of 1255 mg% in one case.

With respect to the mastix reaction our results agree in principle with those of Verwer (61) and Bindrich and Schmidt (48), i.e. we find almost exclusively left curves. Generally our curves are deeper than those noted by Verwer. In the gold sol reaction this difference is even more marked, in that we often get medium or deep curves in the left or middle area, while Verwer's curves obviously are much flatter. We believe that this may be due merely to the choice of cases.

In his thorough study Verwer (61) has also utilized the benzoe sol reaction after Guillain and found a widening of the middle zone of flake separation, as well as an additional peak in the first part of the series.

This fluid syndrome is caused by inflammatory, non-purulent processes in the central nervous system and its membranes. At the present stage of knowledge it seems too daring to make an attempt at the matching of certain fluid types with paraphrased pathologico-histological representations, and we limit

ourselves to the following conclusions:

1. Whenever the neuropathologic examination shows inflammatory processes of the central nervous system and its membranes, changes in the fluid occur invariably, which express themselves primarily by pleocytosis and increase in total albumin, and in a less constant manner by shifting of the globulin - albumin ratio and the pathological curves of the colloid reactions, while no uniform behavior can be recognized in the remaining properties.

2. There is a certain parallel between the fluid changes and the intensity of the inflammatory process, as determined by histological tests.

3. While strong increases in cells and albumin tend to indicate a severe meningeal inflammation, it may be accompanied, in connection with parenchymatous changes, by slightly pathological colloid curves, which however may again be relatively strong.

4. It is impossible to make a diagnosis only on the basis of tests of cerebrospinal fluid, or even on the basis of individual changes. Only the overall picture will furnish valuable diagnostic pointers within the clinical framework.

Monlux, 1949(54), gives a few data on the tests of cerebrospinal fluid in experimental leprospirosis of dogs, in which he seems to deal primarily with infections with Leptospira icterohemorrhagiae. In Weil's disease the fluid can be yellowish (as we found in other diseases marked by jaundice), just as the meninges in such cases show a yellow tint. In spite of the frequent histologically observable and even macroscopic hemorrhages, Monlux did not find erythrocytes. In one animal pleocytosis (lymphocytes) occured, in one case increase of albumin, while sugar invariably maintained normal limits and the mastix and gold sol reactions remained normal (which was to be

expected considering histological findings in leptospiroses).

Attempts at transfer of the disease to hamsters by means of the fluid as well as culture in Schüffner's nutrient medium were ineffectual.

CAT

Wegeforth et al, 1919(65), report on over 1,000 suboccipial taps of cats, when they introduced this method — as Eskuchen in Germany — into clinical neurology. They do not mention, however, whether or not the obtained fluid was more closely examined.

Since diseases of the feline central nervous system are not very frequent, it is not surprising that so little is known about punctures for clinical purposes and pathologic fluid examinations.

The suboccipital tap, principally done in the same manner as that of the dog, offers no difficulties and can be accomplished even with animals that are only a few weeks old. The obtainable fluid amount is small, however, and varies between 10 and 50 drops. The more fluid is allowed to escape, the greater is the danger of hemorrhage from blood vessels of the pia mater.

As far as we have seen to date, the normal fluid of the cat is clear as water, colorless, and contains 0 to 3/3 lymphocytes and total albumin up to 12 mg%. Sugar content amounted to a medial 85%, chloride 899 mg%; tests after Nonne-Apelt, Pandy and Weichbrodt were negative, and the normomastix and gold sol curves corresponded to those of the normal dog.

Of two cats from neighboring farms, suffering from cerebellar ataxia, one showed normal fluid, while examinations of the other revealed a positive Pandy and the astonishing pleocytosis of 2600/3 (small and large lymphocytes, monomuclear cells, endothelia). This led to the belief that cerebellar athropies of the cat are based on multiform processes, a fact that was later

proved by histologic tests of several such cases.

In one case of head trauma with focus of softening and hemorrhage in the hypothalamus, we saw bloody fluid with 30,000/3 erythrocytes and 358/3 lymphocytes, polynuclear and gitter cells; Pandy's reaction was positive. In connection with a fresh subdural hematoma above the cerebellum the fluid merely contained blood, with a negative Pandy.

Two Siamese cats with congenital tremor and one tomcat experimentally infected with Leptospira pomona showed normal cerebrospinal fluid proportions.

RABBIT

The rabbit has been used on a large scale for experimental studies of diseases of the human and animal central nervous system, such as neurosyphilis and various viral encephalitides; and the proportions of its cerebrospinal fluid probably have been examined more thoroughly than in all other domestic animals. It is solely for the sake of completeness that we list a compilation of the most important normal values, as established in particular by Yama Oka, Kasahara, 1924(66), Plaut, 1929(67), Pette, Jahnel and Zeki, 1934(68).

The fluid is obtained by means of suboccipital tap of the narcotized animal held in the abdominal or lateral position. Since anesthesia with morphine considerably reduced the fluid pressure, some examiners preferred to puncture without a narcotic.

Appearance	clear as water, colorless
Amount	1.0 to 1.5 ccm
Pressure	40 to 110 mm H_2O (breath fluctuation up to 15 mm)
Specific gravity	1005
Reaction	alkaline

Total albumin	15 to 19 mg%
Nonne-Apelt	negative
Pandy	negative
Sugar	50 to 57 mg%
Chlorides	600 to 730 mg%
Residual nitrogen	5.6 to 16.8 mg%

On the other hand, little is known about the pathological fluid of rabbits diseased by natural causes. In coccidiosis-meningo-encephalitis the following was observed: Pleocytosis up to 74/3 (lymphocytes), increase of total albumin up to 66 mg%, positive reactions after Nonne, Pandy and Weichbrodt. The mastix curve showed pathologic progressions (Zeki, 1929). Similar changes were noted by various authors in clinically normal rabbits, in which histologic examination later revealed granuloma-encephalitis; it must be noted, however, that even normal fluid results may be arrived at in this socalled spontaneous encephalitis.

MONKEY

In order to complete this compilation we shall list the normal values ascertained in various kinds of monkeys by Mollaret, 1934(69). This writer points to the fact that in monkeys differences between lumbar and suboccipital fluid are markedly greater than in man. The suboccipital tap is technically much simpler than the lumbar.

Appearance	clear as water, colorless
Amount	4 to 10 ccm, depending on size
Pressure	very weak, often practically zero
Cells	suboccipital 1 to 3 per cmm lumbar 4 to 10 per cmm

Total albumin	suboccipital 8 to 15 mg% lumbar 20 to 30 mg%
Pandy	negative
Sugar	60 mg%
Blood sugar/fluid sugar	2/1
Chlorides	420 to 500 mg%

Benzoe sol: 0 000 000 000 000 000 to 0 000 001 200 000 000