13th Int. Workshop on Generalized Nets
London, 29 October 2012, 77–82

Diagnostic method before implantation of cerebrospinal fluid draining shunt in infants. A generalized net model

Ludmila Todorova[1], Peter Vassilev[1] and Jivko Surchev[2]

[1] Department of Bioinformatics and Mathematical Modelling
Institute of Biophysics and Biomedical Engineering, Bulgarian Academy Sciences
105 "Acad. G. Bonchev" Str., Sofia–1113, Bulgaria
e-mails: lpt@biomed.bas.bg, peter.vassilev@gmail.com

[2] Department of Neurosurgery, Medical University
1431 Sofia, Bulgaria
e-mail: j_surchev@abv.bg

Abstract: In the present paper, based on retrospective study of 242 patients with implanted cerebrospinal draining shunt due to infantile hydrocephalus, a diagnosis algorithm has been developed. Based on this model is developed a generalized net model (GN model). The implementation of such model in the practice of family physician would aid in the timely diagnosis mitigating unjustified delays and thus reducing the number of consequent complications.

Keywords: Generalized net, Medical diagnostics.
AMS Classification: 68Q85, 92C50.

1 Introduction

Hydrocephalus is a structural illness of the brain, related to disruptions in the processes of formation, circulation and resorption of the cerebrospinal fluid (CSF) [3]. It is one of the most common diagnoses requiring surgical treatment in pediatric neurosurgery worldwide. There are various etiological moments for it [6]. The contemporary treatment of hydrocephalus is based on shunting operations, during which special valve systems for the CSF drainage are installed [4]. The surgical intervention oftentimes is of life-saving nature. Due to it a normal psycho-motoric development of the sick children may be achieved. However, the decision for surgery must be made after careful evaluation for each particular case by taking into account all indications.

For a twenty year period (1984–2003) in the Clinic of Neurosurgery at UH "Alexand-rovska" and later at UMPH "St. Ivan Rilski" Medical University – Sofia were implanted 242 shunts in children with infantile hydrocephalus. All patients were traced for 5 or more years.

On Figure 1 are given the per cent shares of the investigated patients according to their age at the initial implantation.

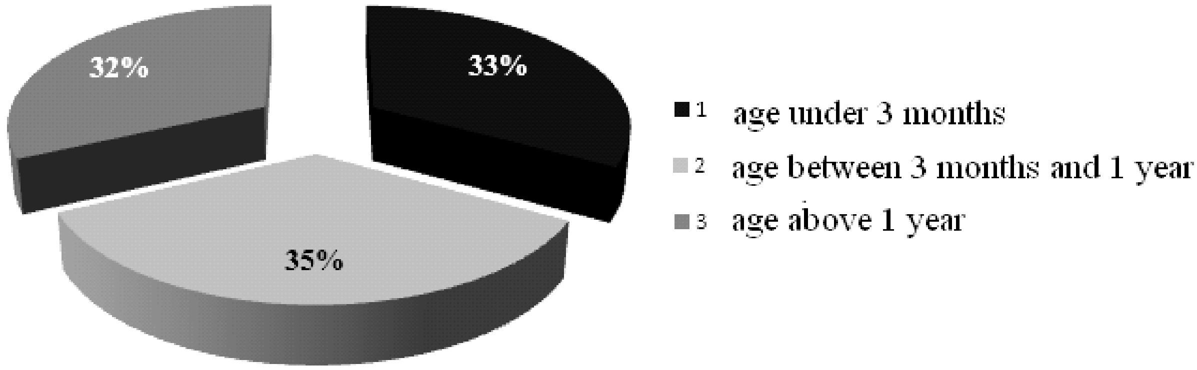

Figure 1: Per cent distribution of the patients by age at initial shunt implantation

Two types of initial shunt operation were applied [2, 5, 7]: *ventriculoatrial anastomosis* (VAA) in 95 of the patients (39%) and Ventriculo-peritoneal *anastomosis* (VPA) – in 147 of the patients (61%). In chronological aspect a priority both nationally and worldwide was given to atrial valves, under which the CSF is drained in the right atrium of the heart. Later, due to severe complications of the ventriculoatrial shunts as a result of many searches for other areas to drain the CSF the peritoneal cavity has been established as alternative due to its great resorbtive capabilities. Less application were found in other cavities – thoracic cavity, urinary bladder, large intestine, etc.

Diagnostic methods before initial shunt implantation

For the youngest patients starting from the neonatal or pediatric ward a transfontanelle brain echography is performed**.** If there is evidence for ventriculomegaly they are being observed and if the evidence persist they are consulted by neurosurgeon. All of the patients underwent pre-surgical computed tomography (CT) scan.

For older children in monthly age during the regular pediatric consultation a measurement of the head circumference is observed. If there is abnormal enlargement, larger size of the frontal fontanelle or its late closure, the children were also consulted by neurosurgeon and a CT scan was made.

At a later age (over 1 year with closed fontanelle) the shape nad size of the head are indications which lead the pediatrician to the diagnosis of hydrocephalus.

CT scan is used to determine the size of the ventricular system as well as the type of hydrocephalus (obstructive or communicating). In this manner other etiological factors (tumors, dysraphism etc) are eliminated. In the last 10 years of tracking magnetic resonance imaging (MRI) is also used – examination with much greater capabilities. In addition to the size and type of the internal hydrocephalus the cerebrospinal fluid flow through the aqueduct is also examined.

Initial implantation of ventruclar shunt

A) **Ventriculoatrial anastomosis *(VAA)* ventricular-atrial anastomosis Ventriculo-Atrial (*VA*) *Shunt***

Ventriculoatrial anastomosis is technically implemented by cutting trepanation opening in the frontal or occipital region of the typical place. The correct localization of the cutting trepanation, together with the precise determination of the direction and length of the ventricular catheter are prerequisites for avoiding the danger of obstructing plexus chorioideus. The length is determined by pre-surgical X-ray of the chest, taking into account that the right atrium is projected on the level fourth-fifth intercostals space.

B) **Ventriculo-peritoneal anastomosis *(VPA)* Ventriculoperitoneal (*VP*) *shunt***

The difference in this type of operations, established later, is in the cavity where the cerebrospinal fluid is drained. There is no difference in implanting the ventricular catheter, subcutaneous tunneling, valve mechanism implantation. There are different localizations of the insertion of the peritoneal catheter: through the middle line of the abdominal wall above and below the navel; in McBurney's point and its symmetrical to the left; by the projected sideline of m. rectus abdominis bipartite, etc.

2 Generalized Net Model

A generalized net model [1] is presented on Figure 2. The initial parameters of the tokens entering the net are the vectors describing the patients: $X = (x_1, x_2, ..., x_n)$ where $x_1, x_2, ..., x_n$ are data vectors, representing each patient. The dimension of the vectors $x_1, x_2, ..., x_n$ is determined by the number of features with which each pattern is represented.

The initial characteristic of the token α in place l_1 is:

"Patient data",

which is the data of all preliminary medical examinations of the patient. These data necessarily should include: patient's age; head circumference; size of the front fontanelle; growth of the front fontanel – abnormal or normal; closure of the front fontanelle – whether it corresponds to the patient's age.

$$Z_1 = \langle \{l_1, l_{3,1}, l_{4,2}, l_{5,2}, l_{8,2}\}, \{l_{2,1}, l_{2,2}, l_{2,3}\}, r_1 \rangle$$

where

$$r_1 = \begin{array}{c|ccc} & l_{2,1} & l_{2,2} & l_{2,3} \\ \hline l_1 & w_{1,2,1} & w_{1,2,2} & w_{1,2,3} \\ l_{3,1} & w_{3.1,2,1} & w_{3.1,2,2} & w_{3.1,2,3} \\ l_{4,2} & false & w_{4.2,2,2} & w_{4.2,2,3} \\ l_{5,2} & false & false & w_{5.2,2,3} \\ l_{8,2} & w_{8.2,2,1} & w_{8.2,2,2} & w_{8.2,2,3} \end{array}$$

and the predicates in the index matrix have the form:

- $w_{1,2,1} = w_{3.1,2,1} = w_{8.1,2,1} =$ "patient's age $\leq$ 3 months";
- $w_{1,2,2} = w_{3.1,2,2} = w_{4.2,2,2} = w_{8.1,2,2} =$ "patient's age between 3 months and 12 months";
- $w_{1,2,3} = w_{3.1,2,3} = w_{4.2,2,3} = w_{5.2,2,3} = w_{8.2,2,1} =$ "patient's age over 12 months".

$$Z_2 = \langle \{l_{2,1}\}, \{l_{3,1}, l_{3,2}\}, r_2 \rangle$$

where

$$r_2 = \begin{array}{c|cc} & l_{3,1} & l_{3,2} \\ \hline l_{2,1} & w_{2,1,3,1} & w_{2,1,3,2} \end{array}$$

and the predicates in the index matrix have the form:

- $w_{2,1,3,1} =$ "the patient has evidence for ventriculomegaly";
- $w_{2,1,3,2} =$ "the patient has no evidence for ventriculomegaly".

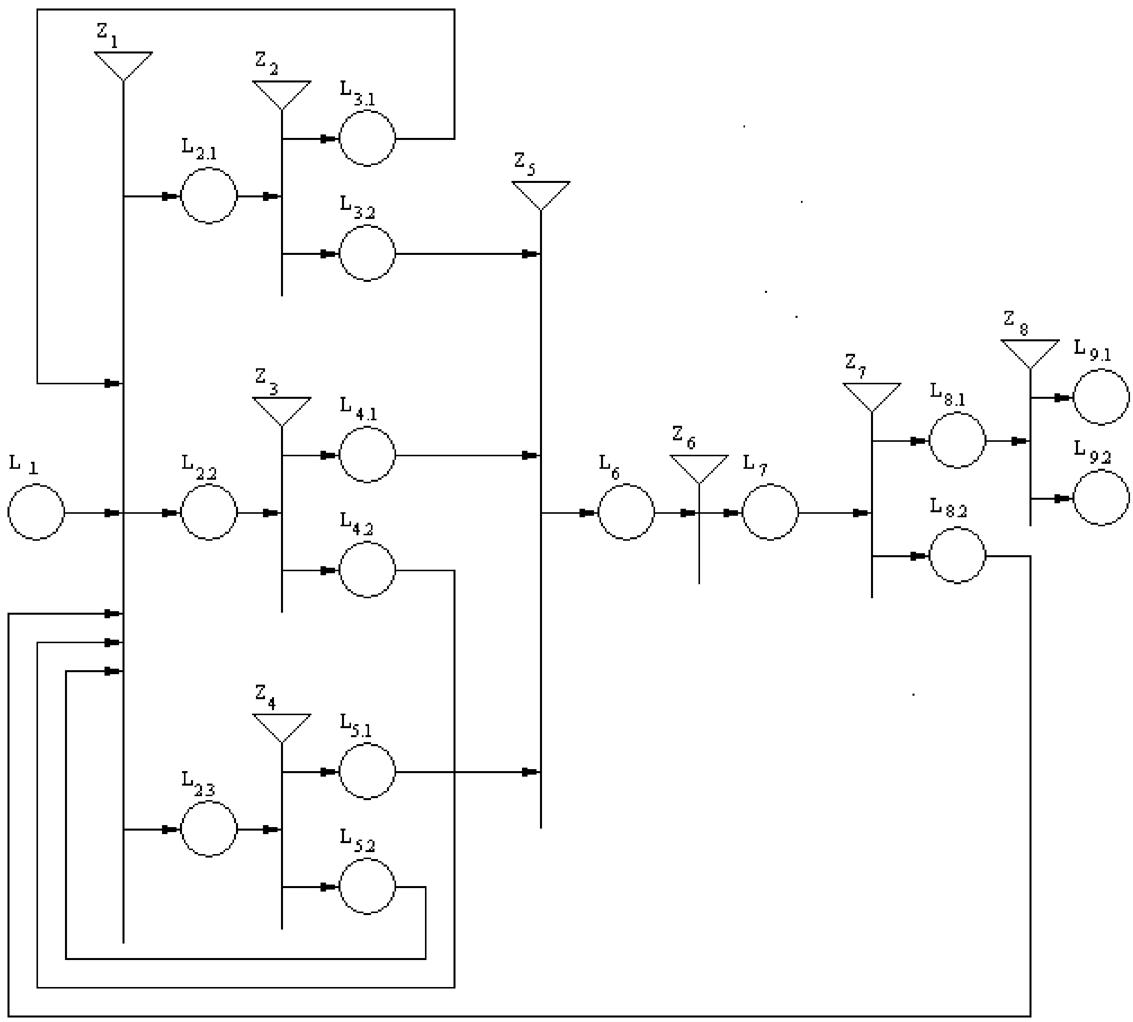

Figure 2: GN model of implantation of cerebrospinal fluid draining shunt in infants

$$Z_3 = \langle \{l_{2.2}\}, \{l_{4.1}, l_{4.2}\}, r_3 \rangle$$

where

$$r_3 = \begin{array}{c|cc} & l_{4,1} & l_{4,2} \\ \hline l_{2,2} & w_{2,2,4,1} & w_{2,2,4,2} \end{array}$$

and the predicates in the index matrix have the form:

- $w_{2,2,4,1}$ = "the patient has evidence for abnormal growth of the frontal fontanelle or for the late closure of the front fontenelle or for large size of the front fontanelle",
- $w_{2,2,4,2}$ = "the patient has no evidence for abnormal growth of the frontal fontanelle and for the late closure of the front fontenelle and for large size of the frontal fontanelle".

$$Z_4 = \langle \{l_{2.3}\}, \{l_{5.1}, l_{5.2}\}, r_4 \rangle,$$

where

$$r_4 = \begin{array}{c|cc} & l_{5,1} & l_{5,2} \\ \hline l_{2,3} & w_{2,3,5,1} & w_{2,3,5,2} \end{array}$$

and the predicates in the index matrix have the form:

- $w_{2,3,5,1}$ = "the patient has evidence for infantile hydrocephalus according to the shape of the head or to large circumference";
- $w_{2,3,5,2}$ = "the patient has no evidence for infantile hydrocephalus according to the shape of the head and has normal circumference".

$$Z_5 = \langle \{l_{3.2}, l_{4.1}, l_{5.1}\}, \{l_6\}, r_5 \rangle,$$

where

$$r_5 = \begin{array}{c|c} & l_6 \\ \hline l_{3,2} & true \\ l_{4,1} & true \\ l_{5,1} & true \end{array}$$

Each of the tokens goes to place l_6 with characteristic "Consultation with neurosurgeon required (Name, Clinic)".

$$Z_6 = \langle \{l_6\}, \{l_7\}, r_6 \rangle$$

where

$$r_6 = \begin{array}{c|c} & l_6 \\ \hline l_7 & true \end{array}$$

$$Z_7 = \langle \{l_7\}, \{l_{8.1}, l_{8.2}\}, r_7 \rangle$$

where

$$r_7 = \begin{array}{c|cc} & l_{8,1} & l_{8,2} \\ \hline l_7 & w_{7,8,1} & w_{7,8,2} \end{array}$$

and the predicates in the index matrix have the form:

- $w_{7,8,1}$ = "implantation of cerebrospinal fluid shunt is required",
- $w_{7,8,2}$ = "implantation of cerebrospinal fluid shunt is not required".

$$Z_7 = \langle \{l_8\}, \{l_{9.1}, l_{9.2}\}, r_8 \rangle,$$

where

$$r_8 = \begin{array}{c|cc} & l_{9,1} & l_{9,2} \\ \hline l_8 & w_{8,9,1} & w_{8,9,2} \end{array}$$

and the predicates in the index matrix have the form:

- $w_{8,9,1}$ = “shunt surgery of type VAA is required”;
- $w_{8,9,2}$= “shunt surgery of type VPA is required”.

3 Conclusion

The variety of etiological factors, leading to infantile hydrocephalus, as well as the fact, that there are forms of hydrocephalus, which are predominant at early age, which progress slowly and with periods without complaints, sometimes make difficult the timely diagnosis. However, it is especially important since:

- Oftentimes is of life-saving importance;
- Ensures normal psychomotorical development of the sick children.

Due to these reasons the developed GN model may aid the family doctors or to serve in the training process of young specialists in the field of neurosurgery.

3 Acknowledgements

This research has been partially funded by Bulgarian National Science Fund under Grant Ref. No. DMU-03-38 “Management and modelling of biomedical processes and information with the application of generalized nets and linked data”.

References

[1] Atanassov, K., *On Generalized Nets Theory*. “Prof. M. Drinov” Academic Publishing House, Sofia, 2007.

[2] Cochrane, D. D, J. Kestle. Ventricular shunting for hydrocephalus in children: Patients, procedures, surgeons and institutions in English Canada, *European Journal of Pediatric Surgery*, Vol. 12, 2002, No. 1, 6–11.

[3] Di Rocco, F., M. Garnett, T. Roujeau, S. Puget, D. Renier, M. Zerah, C. Sainte-Rose. Neurosurgery, *European Manual of Medicine*, Hydrocephalus, Springer. 2010;7:539–543.

[4] Drake, J. M., J. R. Kestle, S. Tuli. CSF shunts: 50 years on past, present and future. *Childs Nerv Syst.* Vol. 16, 2000, 800–804.

[5] Lumenta, C. B., U. Skotarczak. Long-term follow up in 233 patients with congenital hydrocephalus. *Child's Nervous System.* Vol. 11, 1995, No. 3, 173–175.

[6] Oi, S. Hydrocephalus research update-controversies in definition and classification of hydrocephalus. *Neurologia Medico-Chirurgica*. Vol. 50, 2010, No. 9, 859–869.

[7] Paulsen, A. H., T. Lundar, K.-F. Lindegaard. Twenty-year outcome in young adults with childhood hydrocephalus: Assessment of surgical outcome, work participation, and health-related quality of life - Clinical article. *Journal of Neurosurgery: Pediatrics*. Vol. 6, 2010, No. 6, 527–535.