

# Neuroblastoma Histopathology Reporting Guide



Family/Last name  Date of birth

Given name(s)

Patient identifiers  Date of request  Accession/Laboratory number

Elements in **black text** are **CORE**. Elements in **grey text** are **NON-CORE**.

SCOPE OF THIS DATASET

indicates multi-select values  indicates single select values

## CLINICAL INFORMATION (Note 1)

Information not provided

### Age

- Information not provided
- <18 months
- ≥18 months and <5 years
- ≥5 years

### Preoperative treatment

- Information not provided
- No known prior preoperative therapy
- Prior preoperative therapy, *specify*

### Prior biopsy

- Information not provided
- No prior biopsy
- Prior biopsy
  - Needle/core biopsy
  - Excisional/open biopsy
  - Other, *specify*

### Known cancer predisposition syndrome, *specify*

### Other clinical information, *specify*

## OPERATIVE PROCEDURE (Note 2)

- Not specified
- Resection
- Open biopsy
- Needle core biopsy
- Fine needle aspiration (FNA)
- Bone marrow aspirate/core biopsy
- Other, *specify*

## SPECIMEN DIMENSIONS (Note 3)

x  x

## TUMOUR SITE (Note 4)

- Not specified
- Adrenal/periadrenal
- Retroperitoneal, nonadrenal
- Thoracic paraspinal
- Cervical region
- Other, *specify*



- Primary site
- Metastatic site

## TUMOUR DIMENSIONS (Note 5)

(Applicable to primary resections only)

Greatest dimension  mm

Additional dimensions  mm x

Cannot be assessed, *specify*

## BLOCK IDENTIFICATION KEY (Note 6)

(List overleaf or separately with an indication of the nature and origin of all tissue blocks)

## HISTOLOGICAL TUMOUR TYPE (select all that apply) (Note 7)

(Value list based on the World Health Organization Classification of Paediatric Tumours (2022))

- Neuroblastoma
- Ganglioneuroblastoma, intermixed
- Ganglioneuroma
- Ganglioneuroblastoma, nodular
- Other, *specify*

**DEGREE OF DIFFERENTIATION (Note 8)**

*(Applicable to neuroblastoma or nodules of ganglioneuroblastoma, nodular)*

- Undifferentiated
- Poorly differentiated
- Differentiating
- Cannot be determined, *specify*

**MITOTIC-KARYORRHECTIC INDEX (MKI) (Note 9)**

*(Applicable to neuroblastoma and ganglioneuroblastoma, nodular tumour tissue)*

- Low (<100 per 5,000 cells; <2%)
- Intermediate (100-200 per 5,000 cells; 2-4%)
- High (>200 per 5,000 cells; >4%)
- Cannot be determined, *specify*

**PROGNOSTIC CLASSIFICATION (Note 10)**

*(Based on the International Neuroblastoma Pathology Committee classification)*

- Favourable
- Favourable, based on review of limited material
- Unfavourable
- Cannot be determined, *specify*

**TREATMENT EFFECT (Note 11)**

- Not identified
- Present

**LYMPH NODE STATUS (Note 12)**

- Cannot be assessed
- No nodes submitted or found

Number of lymph nodes examined

- Not involved
- Involved

Number of involved lymph nodes

- Number cannot be determined

Location of involved lymph nodes, *specify*

**ANCILLARY STUDIES (Note 13)**

- Not performed
- Performed

**MYCN status**

- Not applicable
- Cannot be determined
- Pending
- Not amplified
- Amplified
- Gain

**DNA content**

DNA ploidy, *record method*

- DNA index 1.0 (diploid)
- DNA index >1.0 (hyperdiploid)
- DNA index, *specify value*

Other, *specify*

AND/OR

CNV, *record method and result*

**Immunohistochemistry, *specify antibodies and results***

**Other (e.g., ALK), *record test(s), methodology and results***

**Representative blocks for ancillary studies, *specify those blocks best representing tumour and/or normal tissue for further study***

**ADDITIONAL MATERIAL FOR BIOLOGICAL/GENETIC ANALYSIS** (Note 14)

**Material available**

- No
- Yes
- Not histological assessed
- Histologically assessed



**Viable tumour present**

- No
- Yes

% viable tumour present

% neuroblastic cells

% Schwann cells

% other cells (e.g., lymphoid cells, fibroblasts)

**HISTOLOGICALLY CONFIRMED DISTANT METASTASIS** (Note 15)

- Not identified
- Present (select all that apply)
- Liver
- Skin
- Bone marrow



Percentage of haemopoietic bone marrow replaced by tumour

- Cannot be determined
- ≤5%
- >5%, specify  %

Bone, specify site(s)

Soft tissue, specify site(s)

Other, specify site(s)

## Definitions

### CORE elements

CORE elements are those which are essential for the clinical management, staging or prognosis of the cancer. These elements will either have evidentiary support at Level III-2 or above (based on prognostic factors in the National Health and Medical Research Council (NHMRC) levels of evidence<sup>1</sup>). In rare circumstances, where level III-2 evidence is not available an element may be made a CORE element where there is unanimous agreement by the Dataset Authoring Committee (DAC). An appropriate staging system e.g., Pathological TNM staging would normally be included as a CORE element.

Non-morphological testing e.g., molecular or immunohistochemical testing is a growing feature of cancer reporting. However, in many parts of the world this type of testing is limited by the available resources. In order to encourage the global adoption of ancillary tests for patient benefit, International Collaboration on Cancer Reporting (ICCR) recommends that some ancillary testing in ICCR Datasets is included as CORE elements. Where the technical capability does not yet exist, laboratories may consider temporarily using these data elements as NON-CORE items.

The summation of all CORE elements is considered to be the minimum reporting standard for a specific cancer.

### NON-CORE elements

Non-core elements are those which are unanimously agreed should be included in the dataset but are not supported by level III-2 evidence. These elements may be clinically important and recommended as good practice but are not yet validated or regularly used in patient management.

Key information other than that which is essential for clinical management, staging or prognosis of the cancer such as macroscopic observations and interpretation, which are fundamental to the histological diagnosis and conclusion e.g., macroscopic tumour details, may be included as either CORE or NON-CORE elements by consensus of DAC.

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## Scope

The dataset has been developed for the pathological reporting of biopsy and resection specimens of paediatric peripheral neuroblastic tumours.

Most such tumours in adults are benign ganglioneuromas; there is a paucity of evidence to support classification and treatment guidelines of neuroblastomas and ganglioneuroblastomas in patients over 10 years old due to their infrequency.<sup>2</sup>

In those rare cases where more than one primary tumour is present, separate datasets should be completed for each neoplasm.

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## Note 1 – Clinical information (Core and Non-core)

### Age

More than 50 years ago, Breslow and McCann reported that both age and stage were strongly prognostic of survival in children with neuroblastoma.<sup>3</sup> This work led to a convenient cut-off of 365 days to define favourable versus unfavourable age. Decades later, London et al (2005),<sup>4</sup> analysed the influence of age on outcome in 3,666 patients in an effort to identify a statistically optimal age cut-off. Although the prognostic contribution of age to outcome was determined to be continuous in nature, statistical support for an age cut-off of 547 days was identified, and this cut-off has subsequently been integrated into cooperative group neuroblastoma risk classification systems.

Tumour histology is another powerful prognostic marker in neuroblastoma. Age is an integral component of the Shimada histologic classification, first described in 1984,<sup>5</sup> and the International Neuroblastoma Pathology Classification (INPC), a system that is based on the Shimada classification with minor modifications.<sup>6</sup> Interestingly, the review of 227 cases by the INPC Committee in 1999 demonstrated the prognostic significance of an age cut-off of 1.5 years, which is similar to the cut-off reported by London and colleagues.<sup>4</sup> Another prognostic age cut-off of five years was also identified.

### Preoperative treatment/prior biopsy

The morphologic appearance of a peripheral neuroblastic tumour may change over time, either spontaneously or in response to treatment. Stage MS disease in infants may spontaneously regress, with tumour cells undergoing apoptosis and/or differentiation, and in some cases leaving little if any histologic evidence of their prior existence.<sup>7</sup> Undifferentiated and poorly differentiated neuroblastomas, as well as ganglioneuroblastomas, may undergo maturation in response to therapy, with increased differentiation of neuroblasts, increased stromal content, and lower mitotic-karyorrhectic index (MKI).<sup>8</sup> The INPC classification was designed to categorise and risk-stratify pre-treatment neuroblastic tumours and, because of the potential for therapy-induced changes, is not suitable for use with post-treatment tumours. The clinical significance of post-therapy histologic features, if any, remains unknown.<sup>8,9</sup>

Knowledge of a prior biopsy is not only useful because it suggests likely administration of therapy in the interval period, but because comparison with the previous sampling can yield important clues about the identity of the tumour. For example, an initial biopsy that has mature ganglion cells in a stroma-rich background and a second biopsy with poorly differentiated neuroblasts and scant stroma would suggest a ganglioneuroblastoma, nodular. Additionally, canonical ‘biopsy site changes’ such as hemosiderin-laden macrophages, fibrosis, and inflammation could be explained by a prior procedure. The heterogeneity of peripheral neuroblastic tumours can be problematic on small biopsies and, thus, all information from all biopsies should be taken into account.

### Cancer predisposition syndromes

An inherited predisposition to neuroblastoma has been estimated in 1-2% of patients with newly diagnosed neuroblastic tumours,<sup>10,11</sup> and a larger number of cases are likely to be identified with increased use of next generation sequencing of germline DNA. The genes most commonly altered in inherited neuroblastoma are *ALK* and *PHOX2B*. Other cancer predisposition syndromes (CPS) that may include neuroblastic tumours are RASopathy syndromes, Beckwith-Wiedemann syndrome, Li-Fraumeni syndrome and DNA repair disorders.

Characteristics that may suggest CPS include a family history of neuroblastic and/or other tumours, bilateral and/or multifocal tumours. A subset of these CPS may also have associated findings. Clinical features that suggest a *PHOX2B* germline mutation include a personal or family history of Congenital Central Hypoventilation Syndrome (CCHS) and/or Hirschsprung disease. Since patients with CPS may have multifocal

tumours it is possible that the histology and biomarkers may differ between specimens and thus, require separate analyses.

#### Other clinical information

Although a diagnosis of a neuroblastic tumour can almost always be made on pathologic grounds, the patient's clinical history and presentation can be contributory. The results of ancillary testing such as urine catecholamines (homovanillic acid and vanillylmandelic acid), <sup>123</sup>I-*meta*-iodobenzylguanidine scintigraphy, and other imaging studies can support a diagnosis of neuroblastoma. Common clinical presentations depend on the sites of disease and may include respiratory distress, abdominal pain, constipation, hepatomegaly, rash, and fevers. Multiple paraneoplastic syndromes can be associated with neuroblastic tumours including opsoclonus myoclonus ataxia, cerebellar ataxia, Horner syndrome, Hirschsprung disease/CCHS, rapid-onset obesity with hypoventilation, hypothalamic dysfunction, and autonomic dysregulation (ROHHAD), and vasoactive intestinal peptide (VIP)-associated secretory diarrhoea or VIPoma syndrome.

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### **Note 2 – Operative procedure (Core)**

The role of surgery in the treatment of neuroblastoma is evolving.<sup>12-14</sup> Beyond the universal need to obtain adequate tissue for establishing the diagnosis and performing ancillary biologic studies, the purpose and utility of surgery vary according to the risk classification of the patient. Although the previous International Neuroblastoma Staging System (INSS)<sup>15</sup> required lymph node sampling, it is not a part of the currently employed International Neuroblastoma Risk Group Staging System (INRG-SS).<sup>16</sup> Furthermore, there is conflicting data as to the specific impact of the degree of surgical resection on overall survival. The majority of children diagnosed with early stage/very low and low risk tumours can be treated with surgery alone and/or low doses of chemotherapy, and in some cases just observation, if disease is localised with no image-defined risk factors (INRG-SS L1 tumours). The goal of initial treatment for intermediate risk patients is to achieve a reduction in tumour burden (usually 50% or more); this can be achieved through any combination of surgery or chemotherapy. In contrast, children presenting with advanced stage/high risk neuroblastoma often require a multimodal approach to treatment: neoadjuvant chemotherapy, surgery, immunotherapy, myeloablative therapy, and/or radiotherapy. In most studies of advanced stage neuroblastoma, the degree of primary tumour resection has shown no impact on local control or long-term outcomes unless metastatic disease can be controlled.<sup>12,17</sup> Thus, the aim should be gross total resection without mutilation and surgical sequelae. For these reasons, tumour presence at surgical margins is not usually assessed pathologically.

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### **Note 3 – Specimen dimensions (Non-core)**

The size of the specimen received for pathologic examination indicates how representative it may be of the overall tumour histology, guides the number of sections to be submitted for histologic evaluation, and estimates the availability of tissue for ancillary testing such as molecular or genetic analysis.<sup>18,19</sup>

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## **Note 4 – Tumour site (Core)**

The anatomic site of a specimen is an important part of any anatomic pathology report, but is especially critical for neuroblastic tumours in order to help correlate gross and microscopic pathologic findings with image-defined risk factors such as invasion of specific visceral organ structures and infiltration of adjacent organs or tissue, as well as to define metastatic disease.<sup>16</sup> Anatomic site may also correlate with clinical presentation such as sequelae of tumour growth from compression or invasion of adjacent structures, as well as the development of paraneoplastic syndromes.

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## **Note 5 – Tumour dimensions (Core and Non-core)**

Tumour size is not a consideration in the International INRG-SS.<sup>16</sup> However, knowledge of the size of the resected tumour in the clinical laboratory may be useful in correlating with the tumour size as determined by imaging, especially when assessing potential therapeutic response using the Response Evaluation Criteria in Solid Tumours (RECIST) algorithm, which uses the greatest dimension of the tumour.<sup>16,20,21</sup> It may also indicate the availability of tissue for ancillary testing such as molecular or genetic analysis.

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## **Note 6 – Block identification key (Non-core)**

The origin/designation of all tissue blocks should be recorded. This information should ideally be documented in the final pathology report and is particularly important should the need for internal or external review arise. The reviewer needs to be clear about the origin of each block in order to provide an informed specialist opinion. If this information is not included in the final pathology report, it should be available on the laboratory computer system and relayed to the reviewing pathologist. It may be useful to have a digital image of the specimen and record of the origin of the tumour blocks in some cases.

Recording the origin/designation of tissue blocks also facilitates retrieval of blocks for further immunohistochemical or molecular analysis, research studies or clinical trials.

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## Note 7 – Histological tumour type (Core)

Histologic diagnosis of neuroblastic tumours is based on the 2022 World Health Organization (WHO) Classification of Paediatric Tumours, 5<sup>th</sup> edition (Table 1).<sup>22</sup>

**Table 1: World Health Organization classification of neuroblastic tumours.**<sup>22</sup>

Descriptor	ICD-O codes <sup>a</sup>
Neuroblastoma	9500/3
Ganglioneuroblastoma, nodular (and other composite neuroblastic tumours)	9490/3
Ganglioneuroblastoma, intermixed	9490/3
Ganglioneuroma	9490/0

<sup>a</sup> These morphology codes are from the International Classification of Diseases for Oncology, third Edition, second revision (ICD-O-3.2).<sup>23</sup> Behaviour is coded /0 for benign tumours; /1 for unspecified, borderline, or uncertain behaviour; /2 for carcinoma in situ and grade III intraepithelial neoplasia; /3 for malignant tumours, primary site; and /6 for malignant tumours, metastatic site.

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Neuroblastoma is often used as a generic term for all categories of peripheral neuroblastic tumours. According to the International Neuroblastoma Pathology Committee classification, four categories are defined in this group of tumours based on the degree of neuroblastic differentiation and the degree of Schwannian stromal development. They are Neuroblastoma (Schwannian stroma-poor), Ganglioneuroblastoma, intermixed (Schwannian stroma-rich), Ganglioneuroma (Schwannian stroma-dominant) and Ganglioneuroblastoma, nodular (composite, Schwannian stroma-rich/stroma-dominant and stroma-poor).<sup>6,24,25</sup> The presence or absence of Schwannian stromal development is noted in parentheses after the specific tumour category.

### Neuroblastoma (Schwannian stroma-poor) category

Tumours in this category are composed of neuroblastic cells showing various degrees of differentiation. Tumour cells form groups or nests completely or incompletely demarcated by septal tissue where no or limited Schwannian proliferation (comprising less than 50% of tumour tissue) is observed.

### Ganglioneuroblastoma, intermixed (Schwannian stroma-rich) category

Tumours in this category are characterised by the presence of a ganglioneuromatous component with Schwannian stroma development (see below) exceeding 50% of the tissue, where microscopic nests of neuroblastoma are present in an intermixed or randomly distributed pattern. In those microscopic nests, the tumour cells are in various stages of differentiation (often predominantly differentiating neuroblasts) with clearly identifiable naked neuritic processes (neuropile, not covered by Schwann cells) around their cytoplasm. Grossly visible haemorrhagic/necrotic nodules suggestive of aggressive neuroblastomatous growth are absent. Tumours in this category are histologically one step behind the final stage of complete maturation towards ganglioneuroma.

### Ganglioneuroma (Schwannian stroma-dominant) category

Tumours in this category are predominantly composed of Schwannian stroma where maturing and mature ganglion cells are individually distributed or forming small clusters in the stroma. Completely mature ganglion cells are covered with satellite cells. For the sake of avoiding confusion, differentiating neuroblasts and ganglion cells in the peripheral neuroblastic tumours are defined based on the presence or absence of naked neuritic processes (neuropile) detectable around their cytoplasm by haematoxylin and eosin (H&E)



stained section. Neuritic processes of the differentiating neuroblasts are still segmentally naked and not incorporated in the cytoplasm of Schwannian stromal cells, whereas no naked neuritic processes are detected around ganglion cells since they are immediately and completely incorporated and covered by Schwannian stromal cells. Accordingly, no microscopic foci of neuroblastic cells with detectable naked neuritic processes are found in the tumours of this category.

#### Ganglioneuroblastoma, nodular (composite, Schwannian stroma-rich/stroma-dominant and stroma-poor) category

Tumours in this category are composed of multiple clones demonstrating distinct histologies: one or more Neuroblastoma (Schwannian stroma-poor) nodules set within a background of either Ganglioneuroblastoma, intermixed (Schwannian stroma-rich) or Ganglioneuroma (Schwannian stroma-dominant). The neuroblastoma nodules are usually grossly identifiable and often haemorrhagic/necrotic and fragile. In contrast, the Ganglioneuroblastoma, Intermixed/Ganglioneuroma component is tan-yellow and solid/elastic.

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### **Note 8 – Degree of differentiation (Core)**

Based on the grade of neuroblastic differentiation, all tumours in the Neuroblastoma (Schwannian stroma-poor) category and neuroblastoma components of Ganglioneuroblastoma, nodular (composite, Schwannian stroma-rich/stroma-dominant) category are further classified into one of three subtypes (see below) for prognostic distinction (Favourable Histology versus Unfavourable Histology) according to the INPC.<sup>24</sup>

#### Undifferentiated subtype

Tumour cells in this subtype are primitive with a high nuclear:cytoplasmic ratio and no morphologic evidence of neuroblastic differentiation and no neuritic process production. Accordingly, the diagnosis relies heavily on ancillary tests, such as immunohistochemistry and/or molecular/cytogenetic analysis. Some tumours in this subtype present a 'starry-sky' appearance.

#### Poorly differentiated subtype

Tumour cells also show a high nuclear:cytoplasmic ratio, and the diagnosis is supported by identifying neuritic process production of the tumour cells. Classical Homer Wright rosette formation can be seen in some tumours of this subtype. Less than 5% of tumour cells may show features of differentiating neuroblasts (see below).

#### Differentiating subtype

More than 5% of tumour cells demonstrate the appearance of differentiating neuroblasts with synchronous differentiation of the nucleus (enlarged, vesicular and often eccentrically located with a single prominent nucleolus) and the cytoplasm (conspicuous and twice the diameter of nucleus, eosinophilic or amphophilic with or without detectable Nissl bodies). Differentiating neuroblasts usually produce a larger amount of neuritic processes than poorly differentiated neuroblasts.

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## Note 9 – Mitotic Karyorrhectic Index (MKI) (Core)

Mitotic-karyorrhectic index (MKI) is the number of mitotic nuclei and karyorrhectic nuclei per 5,000 neuroblastic cells. Based on the MKI, all tumours in the Neuroblastoma (Schwannian stroma-poor) category and neuroblastoma components of Ganglioneuroblastoma, nodular (composite, Schwannian stroma-rich/stroma-dominant) category are further classified into one of three classes; i.e., Low MKI (<100/5,000 cells), Intermediate MKI (100-200/5,000 cells), and High MKI (>200/5,000 cells), for the prognostic distinction (Favourable Histology versus Unfavourable Histology) according to the INPC.<sup>6,24,26,27</sup>

Following is the step-wise method recommended for determining MKI class:

1. First, estimate background number (denominator) of neuroblastoma cells in a 400X high power field (HPF) of your microscope. The tumour may show uniform cellularity or present different cellular densities from area to area: For example, a densely cellular area may contain 1,000-1500 cells per 400X HPF; a moderately cellular area may contain approximately 800 cells per 400X HPF; and a sparsely cellular area may contain <500 cells per 400X HPF.
2. Scan the tumour tissue by low power view, and determine whether the given tumour has a uniform cellular density or different cellular densities from area to area.
3. Pick representative areas based on the proportion of cellular densities, and count mitotic and karyorrhectic nuclei from each microscopic field (400X) of the given tumour. Karyorrhectic nuclei showing nuclear fragmentation, but not simply hyperchromatic nuclei, are included in the counting.
4. After having counted the total number of mitotic and karyorrhectic nuclei from the representative areas, the MKI is determined by averaging the number per 5,000 (denominator) tumour cells.

Specimens with less than 5,000 cells available for counting (core biopsies with a small proportion of tumour, for example) or with extensive geographic tumour necrosis, are unsuitable for MKI calculation and should be reported as 'Cannot be determined'. Furthermore, MKI determination on bone marrow metastases is discouraged, as it has not been shown to correlate with the MKI of the primary tumour nor to be prognostically useful.

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## Note 10 – Prognostic classification (Core)

The age of the patient and the histologic type (**Note 7 HISTOLOGICAL TUMOUR TYPE**), degree of differentiation (**Note 8 DEGREE OF DIFFERENTIATION**), and MKI (**Note 9 MITOTIC-KARYORRHECTIC INDEX**) of a peripheral neuroblastic tumour are utilised to categorise it as favourable or unfavourable histology according to the INPC classification system (Table 2).<sup>6,24,25</sup> Pathologic classification strongly correlates with prognosis and is used to risk-stratify patients for therapeutic protocols.<sup>4,6,14,24-27</sup> Ganglioneuroblastoma, nodular, and other composite neuroblastic tumours are classified by applying the INPC schema to the highest grade nodule or component of the tumour. When a biopsy or partial resection is performed, there exists a risk of failing to sample an unfavourable nodule or component of these two tumour types; thus, in such cases, a disclaimer about limited sampling should be made.

**Table 2: International Neuroblastoma Pathology Classification (INPC) of neuroblastic tumours.**<sup>6,24,25</sup>

Histologic type	Differentiation	Mitotic-karyorrhectic index (MKI)	Age	Histology
Neuroblastoma	Undifferentiated	Any	Any	Unfavourable
	Poorly differentiated	Low or Intermediate	<18 months	Favourable
			≥18 months	Unfavourable
		High	Any	Unfavourable
	Differentiating	Low	<5 years	Favourable
			≥5 years	Unfavourable
		Intermediate	<18 months	Favourable
			≥18 months	Unfavourable
High		Any	Unfavourable	
Ganglioneuroblastoma, nodular (and other composite neuroblastic tumours)	Classify according to highest grade nodule or component of tumour			
Ganglioneuroblastoma, intermixed	NA	NA	Any	Favourable
Ganglioneuroma	NA	NA	Any	Favourable

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## Note 11 – Treatment effect (Non-core)

Assessment of the amount of residual viable tumour after neoadjuvant systemic treatment and type of histologic response may represent desired information for clinicians in terms of estimation of efficacy of treatment even though there is limited data about the clinical significance or influence on patient prognosis. Treatment effect does not solely consist of necrosis; calcifications, fibrosis, and tumour cell differentiation/maturation should also be considered as response. The amount of remaining viable tumour may be estimated in percent on each histological slide to obtain an average score reflecting the overall response.

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## Note 12 – Lymph node status (Core)

As in most cancer types, lymph node status has historically been an important aspect of neuroblastoma staging (for the INSS) and is therefore regarded a core element in the reporting of these tumours. This includes whether or not such lymph nodes were submitted for pathological investigation, how many lymph nodes were submitted and from what location, and whether they harbored metastatic tumour or not. The INRG-SS, published in 2009, specifies that nodal status is not used to distinguish L1 from L2 disease and that positive locoregional lymph nodes are still compatible with L2 disease, in contrast to distal lymph node metastases that qualify as stage M.<sup>16</sup> For instance, lower mediastinal nodes in combination with an upper abdominal primary tumour and a pelvic primary tumour with inguinal positive lymph nodes would both still

be classified as stage L2 disease. It is evident from the above that close collaboration between surgeon and pathologist is crucial to arrive at the correct staging. Chemotherapeutic effect indicative of the prior presence of tumour within a lymph node, such as calcifications, hemosiderin-laden macrophages, or foci of acellular neuropil should be considered lymph node involvement by tumour.

Although no pertinent literature currently exists on this subject, it might also be relevant to describe the histological aspect of lymph node metastases, in relation to the aspect of the primary tumour, specifying the degree of differentiation and of therapy effect. This, however, is not a requirement for this dataset.

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## Note 13 – Ancillary studies (Core and Non-core)

**MYCN:** *MYCN* amplification is the single most important prognostic marker in neuroblastic tumours and is associated with poorly differentiated or undifferentiated tumours with high MKI.<sup>28</sup> *MYCN* is a proto-oncogene which inhibits cell differentiation and promotes division and apoptosis, biologic activities which correlate well with the histologic features seen in *MYCN*-amplified tumours. Amplification occurs through duplication of the *MYCN* gene locus on chromosome 2p via the formation of double minutes (dmin), small circular extrachromosomal DNA fragments that contain the *MYCN* gene; these may subsequently be reintegrated into the chromosome as heterogeneously staining regions.<sup>29,30</sup> Amplification status is best assessed by fluorescence *in situ* hybridization on formalin-fixed paraffin-embedded or frozen tissue (or less commonly, air-dried touch preparation slides). Signals from a *MYCN*-specific probe are compared to those from a centromeric chromosome 2 probe; tumours with a *MYCN*:control signal ratio of 4 or more are 'amplified', while those with a ratio of more than 1 but less than 3 are considered to have *MYCN* 'gain,' the clinical significance of which is less clear.<sup>31</sup> Notably, some labs may now use copy number analyses (e.g., CGH or SNP arrays) or next generation sequencing approaches to detect *MYCN* amplification status. Analyses of large numbers of patients have also identified two unique subsets of patients with genotype-phenotype discordance: those who have *MYCN* amplification but favourable histology tumours and a good prognosis, and those without *MYCN* amplification who nonetheless have unfavourable histology tumours and dismal prognosis.<sup>31,32</sup> The former appear to not produce functional N-myc protein despite having amplification of the gene, and the latter are often associated with C-myc protein expression or other molecular abnormalities instead.<sup>33,34</sup> C-myc expression is not currently used in the Children's Oncology Group or INRG risk classification systems.<sup>35,36</sup> Depending on the availability of such testing and the laboratory's workflow, the results of *MYCN* amplification status analysis may not be known to the pathologist at the time of diagnosis.

**DNA content:** DNA index is a prognostic factor in infants (<1 year old) with neuroblastoma. A DNA index near diploid/tetraploid is unfavourable, whereas hyperdiploidy is favourable.<sup>37</sup> Most laboratories currently use next generation sequencing or microarrays to determine the DNA index of tumour cells, but some may use the more traditional flow cytometry approach.

**Immunohistochemistry:** Peripheral neuroblastic tumours can usually be diagnosed based on the morphology of their neuroblastic and stromal components, especially in tumours with significant differentiation and/or neuropile content. However, for undifferentiated tumours and in biopsies with limited sampling, immunohistochemistry can be a useful adjunct. Phox2B is one of the most sensitive and specific markers for neuroblastoma, although it is also positive in other neural crest-derived tumours such as paraganglioma/pheochromocytoma.<sup>38,39</sup> Additional stains typically positive in neuroblastic tumours include PGP9.5, CD56, and NB84. The neuroblastic cells are usually positive for synaptophysin and neuron-specific enolase and the Schwannian stromal cells are usually positive for S100 (although these stains are of limited utility due to their nonspecific nature).

*Other Ancillary Studies:* Additional molecular and genetic aberrations may be of prognostic or other clinical significance, and more are being discovered as our knowledge expands; however, their use and availability may vary between laboratories. The anaplastic lymphoma kinase (*ALK*) gene is mutated in 8-10% of sporadic neuroblastic tumours, amplified in about 2% of sporadic tumours, and mutated in the germline of patients with genetic predisposition syndromes that include an increased risk of neuroblastoma (see **Note 1 CLINICAL INFORMATION**).<sup>40,41</sup> Unfortunately, *ALK* immunohistochemistry does not correlate well with gene mutation or amplification status, so sequencing of the kinase regions and/or known mutational hotspots is required. *ALK* aberrations are associated with higher risk disease but may also be amenable to treatment with tyrosine kinase inhibitors such as lorlatinib.

Next generation sequencing assays have been useful in identifying the association of specific segmental chromosomal aberrations including 1p deletion, 11q deletion, and 17 q gain with high risk tumours.<sup>42</sup> Likewise, abnormalities in the telomere maintenance/alternate lengthening of telomeres (*ALT*) pathways can prolong cell survival and recent evidence suggests these alterations are associated with more unfavourable or higher risk disease. Such genes include alpha-thalassemia/mental retardation X-linked syndrome (*ATRX*), with mutations found more commonly in high risk tumours in older children, and increased expression and/or rearrangements of the telomere reverse transcriptase (*TERT*) are associated with a poorer prognosis.<sup>43,44</sup> Although not yet widely used for directing clinical care, *ALT* pathways can be analysed by immunohistochemistry.

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## **Note 14 – Additional material for biological/genetic analysis (Core)**

Determination of *MYCN* amplification status is a critical part of risk stratification for peripheral neuroblastic tumours and additional molecular/genetic testing can be helpful in directing clinical care, especially in patients with recurrent or refractory tumours (see **Note 13 ANCILLARY STUDIES**). Thus, documenting the availability of residual tissue for such testing, including whether it contains sufficient viable tumour for meaningful analysis, is important for the patient's ongoing care.

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## **Note 15 – Histologically confirmed distant metastases (Core)**

Documentation of known metastatic disease is an important part of the pathology report and is part of the INRG-SS.<sup>16</sup> Such information, if available, should be recorded with as much detail as is available including the site, whether the specimen is a histopathology or cytopathology specimen and with reference to any relevant prior surgical pathology or cytopathology specimens. Of note, the International Neuroblastoma Response Criteria Bone Marrow Working Group has proposed a standardised approach to assessing marrow involvement by neuroblastoma which, while not part of the INRG-SS, includes useful guidelines.<sup>45</sup> These include sampling at least two sites (usually bilateral iliac crests), estimating the percent marrow involvement by disease in each specimen (by surface area for cores and by cell number for aspirates), using immunohistochemistry/immunocytochemistry for more sensitive detection, and performing RT-PCR to assess minimal disease.

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## References

- 1 Merlin T, Weston A and Tooher R (2009). Extending an evidence hierarchy to include topics other than treatment: revising the Australian 'levels of evidence'. *BMC Med Res Methodol* 9:34.
- 2 Esiashvili N, Goodman M, Ward K, Marcus RB, Jr. and Johnstone PA (2007). Neuroblastoma in adults: Incidence and survival analysis based on SEER data. *Pediatr Blood Cancer* 49(1):41-46.
- 3 Breslow N and McCann B (1971). Statistical estimation of prognosis for children with neuroblastoma. *Cancer Res* 31(12):2098-2103.
- 4 London WB, Castleberry RP, Matthay KK, Look AT, Seeger RC, Shimada H, Thorner P, Brodeur G, Maris JM, Reynolds CP and Cohn SL (2005). Evidence for an age cutoff greater than 365 days for neuroblastoma risk group stratification in the Children's Oncology Group. *J Clin Oncol* 23(27):6459-6465.
- 5 Shimada H, Chatten J, Newton WA, Jr., Sachs N, Hamoudi AB, Chiba T, Marsden HB and Misugi K (1984). Histopathologic prognostic factors in neuroblastic tumors: definition of subtypes of ganglioneuroblastoma and an age-linked classification of neuroblastomas. *J Natl Cancer Inst* 73(2):405-416.
- 6 Shimada H, Ambros IM, Dehner LP, Hata J, Joshi VV, Roald B, Stram DO, Gerbing RB, Lukens JN, Matthay KK and Castleberry RP (1999). The International Neuroblastoma Pathology Classification (the Shimada system). *Cancer* 86(2):364-372.
- 7 Pritchard J and Hickman JA (1994). Why does stage 4s neuroblastoma regress spontaneously? *Lancet* 344(8926):869-870.
- 8 George RE, Perez-Atayde AR, Yao X, London WB, Shamberger RC, Neuberg D and Diller L (2012). Tumor histology during induction therapy in patients with high-risk neuroblastoma. *Pediatr Blood Cancer* 59(3):506-510.
- 9 Hishiki T, Horie H, Higashimoto Y, Yotsumoto K, Komatsu S, Okimoto Y, Kakuda H, Taneyama Y, Saito T, Terui K, Mitsunaga T, Nakata M, Ochiai H, Hino M, Ando K, Yoshida H and Iwai J (2014). Histological features of primary tumors after induction or high-dose chemotherapy in high-risk neuroblastoma. *Pediatr Surg Int* 30(9):919-926.
- 10 Kamihara J, Bourdeaut F, Foulkes WD, Molenaar JJ, Mossé YP, Nakagawara A, Parareda A, Scollon SR, Schneider KW, Skalet AH, States LJ, Walsh MF, Diller LR and Brodeur GM (2017). Retinoblastoma and Neuroblastoma Predisposition and Surveillance. *Clin Cancer Res* 23(13):e98-e106.
- 11 Goudie C, Witkowski L, Cullinan N, Reichman L, Schiller I, Tachdjian M, Armstrong L, Blood KA, Brossard J, Brunga L, Cacciotti C, Caswell K, Cellot S, Clark ME, Clinton C, Coltin H, Felton K, Fernandez CV, Fleming AJ, Fuentes-Bolanos N, Gibson P, Grant R, Hammad R, Harrison LW, Irwin MS, Johnston DL, Kane S, Lafay-Cousin L, Lara-Corrales I, Larouche V, Mathews N, Meyn MS, Michaeli O, Perrier R, Pike M, Punnett A, Ramaswamy V, Say J, Somers G, Tabori U, Thibodeau ML, Toupin AK, Tucker KM, van Engelen K, Vairy S, Waespe N, Warby M, Wasserman JD, Whitlock JA, Sinnott D, Jabado N, Nathan PC, Shlien A, Kamihara J, Deyell RJ, Ziegler DS, Nichols KE, Dendukuri N, Malkin D, Villani A and Foulkes WD (2021). Performance of the McGill Interactive Pediatric OncoGenetic Guidelines for Identifying Cancer Predisposition Syndromes. *JAMA Oncol* 7(12):1806-1814.

- 12 Ryan AL, Akinkuotu A, Pierro A, Morgenstern DA and Irwin MS (2020). The Role of Surgery in High-risk Neuroblastoma. *J Pediatr Hematol Oncol* 42(1):1-7.
- 13 Fati F, Pulvirenti R, Paraboschi I and Martucciello G (2021). Surgical Approaches to Neuroblastoma: Review of the Operative Techniques. *Children (Basel)* 8(6).
- 14 Croteau N, Nuchtern J and LaQuaglia MP (2021). Management of Neuroblastoma in Pediatric Patients. *Surg Oncol Clin N Am* 30(2):291-304.
- 15 Smith EI, Haase GM, Seeger RC and Brodeur GM (1989). A surgical perspective on the current staging in neuroblastoma--the International Neuroblastoma Staging System proposal. *J Pediatr Surg* 24(4):386-390.
- 16 Monclair T, Brodeur GM, Ambros PF, Brisse HJ, Cecchetto G, Holmes K, Kaneko M, London WB, Matthay KK, Nuchtern JG, von Schweinitz D, Simon T, Cohn SL and Pearson AD (2009). The International Neuroblastoma Risk Group (INRG) staging system: an INRG Task Force report. *J Clin Oncol* 27(2):298-303.
- 17 Holmes K, Pötschger U, Pearson ADJ, Sarnacki S, Cecchetto G, Gomez-Chacon J, Squire R, Freud E, Bysiek A, Matthyssens LE, Metzelder M, Monclair T, Stenman J, Rygl M, Rasmussen L, Joseph JM, Irtan S, Avanzini S, Godzinski J, Björnland K, Elliott M, Luksch R, Castel V, Ash S, Balwierz W, Laureys G, Ruud E, Papadakis V, Malis J, Owens C, Schroeder H, Beck-Popovic M, Trahair T, Forjaz de Lacerda A, Ambros PF, Gaze MN, McHugh K, Valteau-Couanet D and Ladenstein RL (2020). Influence of Surgical Excision on the Survival of Patients With Stage 4 High-Risk Neuroblastoma: A Report From the HR-NBL1/SIOPEN Study. *J Clin Oncol* 38(25):2902-2915.
- 18 College of American Pathologists (2022). *Protocol for the Examination of Biopsy Specimens From Patients With Neuroblastoma*. Available from: [https://documents.cap.org/protocols/Neuroblastoma.Bx\\_4.2.0.0.REL\\_CAPCP.pdf](https://documents.cap.org/protocols/Neuroblastoma.Bx_4.2.0.0.REL_CAPCP.pdf) (Accessed 15th January 2023).
- 19 College of American Pathologists (2022). *Protocol for the Examination of Resection Specimens From Patients With Neuroblastoma*. Available from: [https://documents.cap.org/protocols/Neuroblastoma\\_4.2.0.0.REL\\_CAPCP.pdf](https://documents.cap.org/protocols/Neuroblastoma_4.2.0.0.REL_CAPCP.pdf) (Accessed 15th January 2023).
- 20 Schwartz LH, Seymour L, Litière S, Ford R, Gwyther S, Mandrekar S, Shankar L, Bogaerts J, Chen A, Dancey J, Hayes W, Hodi FS, Hoekstra OS, Huang EP, Lin N, Liu Y, Therasse P, Wolchok JD and de Vries E (2016). RECIST 1.1 - Standardisation and disease-specific adaptations: Perspectives from the RECIST Working Group. *Eur J Cancer* 62:138-145.
- 21 Park JR, Bagatell R, Cohn SL, Pearson AD, Villablanca JG, Berthold F, Burchill S, Boubaker A, McHugh K, Nuchtern JG, London WB, Seibel NL, Lindwasser OW, Maris JM, Brock P, Schleiermacher G, Ladenstein R, Matthay KK and Valteau-Couanet D (2017). Revisions to the International Neuroblastoma Response Criteria: A Consensus Statement From the National Cancer Institute Clinical Trials Planning Meeting. *J Clin Oncol* 35(22):2580-2587.
- 22 WHO Classification of Tumours Editorial Board (ed) (2022). *Pediatric Tumours, WHO Classification of Tumours, 5th edition, Volume 7*. IARC Publications, Lyon.

- 23 Fritz A, Percy C, Jack A, Shanmugaratnam K, Sobin L, Parkin DM and Whelan S (eds) (2020). *International Classification of Diseases for Oncology, Third edition, Second revision ICD-O-3.2*. Available from: [http://www.iacr.com.fr/index.php?option=com\\_content&view=category&layout=blog&id=100&Itemid=577](http://www.iacr.com.fr/index.php?option=com_content&view=category&layout=blog&id=100&Itemid=577) (Accessed 16th December 2022).
- 24 Shimada H, Ambros IM, Dehner LP, Hata J, Joshi VV and Roald B (1999). Terminology and morphologic criteria of neuroblastic tumors: recommendations by the International Neuroblastoma Pathology Committee. *Cancer* 86(2):349-363.
- 25 Peuchmaur M, d'Amore ES, Joshi VV, Hata J, Roald B, Dehner LP, Gerbing RB, Stram DO, Lukens JN, Matthay KK and Shimada H (2003). Revision of the International Neuroblastoma Pathology Classification: confirmation of favorable and unfavorable prognostic subsets in ganglioneuroblastoma, nodular. *Cancer* 98(10):2274-2281.
- 26 Joshi VV, Chatten J, Sather HN and Shimada H (1991). Evaluation of the Shimada classification in advanced neuroblastoma with a special reference to the mitosis-karyorrhexis index: a report from the Childrens Cancer Study Group. *Mod Pathol* 4(2):139-147.
- 27 Teshiba R, Kawano S, Wang LL, He L, Naranjo A, London WB, Seeger RC, Gastier-Foster JM, Look AT, Hogarty MD, Cohn SL, Maris JM, Park JR and Shimada H (2014). Age-dependent prognostic effect by Mitosis-Karyorrhexis Index in neuroblastoma: a report from the Children's Oncology Group. *Pediatr Dev Pathol* 17(6):441-449.
- 28 Goto S, Umehara S, Gerbing RB, Stram DO, Brodeur GM, Seeger RC, Lukens JN, Matthay KK and Shimada H (2001). Histopathology (International Neuroblastoma Pathology Classification) and MYCN status in patients with peripheral neuroblastic tumors: a report from the Children's Cancer Group. *Cancer* 92(10):2699-2708.
- 29 Yoshimoto M, Caminada De Toledo SR, Monteiro Caran EM, de Seixas MT, de Martino Lee ML, de Campos Vieira Abib S, Vianna SM, Schettini ST and Anderson Duffles Andrade J (1999). MYCN gene amplification. Identification of cell populations containing double minutes and homogeneously staining regions in neuroblastoma tumors. *Am J Pathol* 155(5):1439-1443.
- 30 Storlazzi CT, Lonoce A, Guastadisegni MC, Trombetta D, D'Addabbo P, Daniele G, L'Abbate A, Macchia G, Surace C, Kok K, Ullmann R, Purgato S, Palumbo O, Carella M, Ambros PF and Rocchi M (2010). Gene amplification as double minutes or homogeneously staining regions in solid tumors: origin and structure. *Genome Res* 20(9):1198-1206.
- 31 Suganuma R, Wang LL, Sano H, Naranjo A, London WB, Seeger RC, Hogarty MD, Gastier-Foster JM, Look AT, Park JR, Maris JM, Cohn SL, Amann G, Beiske K, Cullinane CJ, d'Amore ES, Gambini C, Jarzembowski JA, Joshi VV, Navarro S, Peuchmaur M and Shimada H (2013). Peripheral neuroblastic tumors with genotype-phenotype discordance: a report from the Children's Oncology Group and the International Neuroblastoma Pathology Committee. *Pediatr Blood Cancer* 60(3):363-370.
- 32 Wang LL, Suganuma R, Ikegaki N, Tang X, Naranjo A, McGrady P, London WB, Hogarty MD, Gastier-Foster JM, Look AT, Park JR, Maris JM, Cohn SL, Seeger RC and Shimada H (2013). Neuroblastoma of undifferentiated subtype, prognostic significance of prominent nucleolar formation, and MYC/MYCN protein expression: a report from the Children's Oncology Group. *Cancer* 119(20):3718-3726.



- 33 Ikegaki N and Shimada H (2019). Subgrouping of Unfavorable Histology Neuroblastomas With Immunohistochemistry Toward Precision Prognosis and Therapy Stratification. *JCO Precis Oncol* 3.
- 34 Shimada H and Ikegaki N (2022). Genetic and Histopathological Heterogeneity of Neuroblastoma and Precision Therapeutic Approaches for Extremely Unfavorable Histology Subgroups. *Biomolecules* 12(1).
- 35 Cohn SL, Pearson AD, London WB, Monclair T, Ambros PF, Brodeur GM, Faldum A, Hero B, Iehara T, Machin D, Mosseri V, Simon T, Garaventa A, Castel V and Matthay KK (2009). The International Neuroblastoma Risk Group (INRG) classification system: an INRG Task Force report. *J Clin Oncol* 27(2):289-297.
- 36 Irwin MS, Naranjo A, Zhang FF, Cohn SL, London WB, Gastier-Foster JM, Ramirez NC, Pfau R, Reshmi S, Wagner E, Nuchtern J, Asgharzadeh S, Shimada H, Maris JM, Bagatell R, Park JR and Hogarty MD (2021). Revised Neuroblastoma Risk Classification System: A Report From the Children's Oncology Group. *J Clin Oncol* 39(29):3229-3241.
- 37 Look AT, Hayes FA, Shuster JJ, Douglass EC, Castleberry RP, Bowman LC, Smith EI and Brodeur GM (1991). Clinical relevance of tumor cell ploidy and N-myc gene amplification in childhood neuroblastoma: a Pediatric Oncology Group study. *J Clin Oncol* 9(4):581-591.
- 38 Bielle F, Fréneaux P, Jeanne-Pasquier C, Maran-Gonzalez A, Rousseau A, Lamant L, Paris R, Pierron G, Nicolas AV, Sastre-Garau X, Delattre O, Bourdeaut F and Peuchmaur M (2012). PHOX2B immunolabeling: a novel tool for the diagnosis of undifferentiated neuroblastomas among childhood small round blue-cell tumors. *Am J Surg Pathol* 36(8):1141-1149.
- 39 Hata JL, Correa H, Krishnan C, Esbenshade AJ, Black JO, Chung DH and Mobley BC (2015). Diagnostic utility of PHOX2B in primary and treated neuroblastoma and in neuroblastoma metastatic to the bone marrow. *Arch Pathol Lab Med* 139(4):543-546.
- 40 Mossé YP, Laudenslager M, Longo L, Cole KA, Wood A, Attiyeh EF, Laquaglia MJ, Sennett R, Lynch JE, Perri P, Laureys G, Speleman F, Kim C, Hou C, Hakonarson H, Torkamani A, Schork NJ, Brodeur GM, Tonini GP, Rappaport E, Devoto M and Maris JM (2008). Identification of ALK as a major familial neuroblastoma predisposition gene. *Nature* 455(7215):930-935.
- 41 Janoueix-Lerosey I, Lequin D, Brugières L, Ribeiro A, de Pontual L, Combaret V, Raynal V, Puisieux A, Schleiermacher G, Pierron G, Valteau-Couanet D, Frebourg T, Michon J, Lyonnet S, Amiel J and Delattre O (2008). Somatic and germline activating mutations of the ALK kinase receptor in neuroblastoma. *Nature* 455(7215):967-970.
- 42 Schleiermacher G, Mosseri V, London WB, Maris JM, Brodeur GM, Attiyeh E, Haber M, Khan J, Nakagawara A, Speleman F, Noguera R, Tonini GP, Fischer M, Ambros I, Monclair T, Matthay KK, Ambros P, Cohn SL and Pearson AD (2012). Segmental chromosomal alterations have prognostic impact in neuroblastoma: a report from the INRG project. *Br J Cancer* 107(8):1418-1422.

- 43 Pugh TJ, Morozova O, Attiyeh EF, Asgharzadeh S, Wei JS, Auclair D, Carter SL, Cibulskis K, Hanna M, Kiezun A, Kim J, Lawrence MS, Lichenstein L, McKenna A, Peadarallu CS, Ramos AH, Shefler E, Sivachenko A, Sougnez C, Stewart C, Ally A, Birol I, Chiu R, Corbett RD, Hirst M, Jackman SD, Kamoh B, Khodabakshi AH, Krzywinski M, Lo A, Moore RA, Mungall KL, Qian J, Tam A, Thiessen N, Zhao Y, Cole KA, Diamond M, Diskin SJ, Mosse YP, Wood AC, Ji L, Sposto R, Badgett T, London WB, Moyer Y, Gastier-Foster JM, Smith MA, Guidry Auvil JM, Gerhard DS, Hogarty MD, Jones SJ, Lander ES, Gabriel SB, Getz G, Seeger RC, Khan J, Marra MA, Meyerson M and Maris JM (2013). The genetic landscape of high-risk neuroblastoma. *Nat Genet* 45(3):279-284.
- 44 Cheung NK, Zhang J, Lu C, Parker M, Bahrami A, Tickoo SK, Heguy A, Pappo AS, Federico S, Dalton J, Cheung IY, Ding L, Fulton R, Wang J, Chen X, Becksfort J, Wu J, Billups CA, Ellison D, Mardis ER, Wilson RK, Downing JR and Dyer MA (2012). Association of age at diagnosis and genetic mutations in patients with neuroblastoma. *Jama* 307(10):1062-1071.
- 45 Burchill SA, Beiske K, Shimada H, Ambros PF, Seeger R, Tytgat GA, Brock PR, Haber M, Park JR and Berthold F (2017). Recommendations for the standardization of bone marrow disease assessment and reporting in children with neuroblastoma on behalf of the International Neuroblastoma Response Criteria Bone Marrow Working Group. *Cancer* 123(7):1095-1105.