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de Swart, Louise, Smith, Alexandra Gwen [orcid.org/0000-0002-1111-966X](https://orcid.org/0000-0002-1111-966X), Haase, Detlef et al. (26 more authors) (2018) Prognostic impact of a suboptimal number of analyzed metaphases in normal karyotype lower-risk MDS. *Leukemia research*. pp. 21-26. ISSN 0145-2126

<https://doi.org/10.1016/j.leukres.2018.01.022>

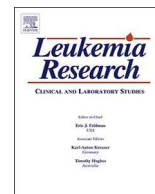
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## Research paper

## Prognostic impact of a suboptimal number of analyzed metaphases in normal karyotype lower-risk MDS



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## ARTICLE INFO

## Keywords:

Myelodysplastic syndromes

Metaphases

Karyotype

Cytogenetics

Lower-risk

Overall survival

Progression-free survival

## ABSTRACT

Conventional karyotype is one of the most relevant prognostic factors in MDS. However, about 50% of patients with MDS have a normal karyotype. Usually, 20–25 normal metaphases (nMP) are considered to be optimal to exclude small abnormal clones which might be associated with poor prognosis. This study evaluated the impact of examining a suboptimal number of metaphases in patients recruited to the EUMDS Registry with low and intermediate-1 risk according to IPSS. Only 179/1049 (17%) of patients with a normal karyotype had a suboptimal number of nMP, defined as less than 20 metaphases analyzed. The outcome (overall survival and progression-free survival) of patients with suboptimal nMP was not inferior to those with higher numbers of analyzed MP both in univariate and multivariate analyses. For patients with an abnormal karyotype, 224/649 (35%) had a suboptimal number of MP assessed, but this did not impact on outcome. For patients with a normal karyotype and suboptimal numbers of analyzable metaphases standard evaluation might be acceptable for

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general practice, but we recommend additional FISH-analyses or molecular techniques, especially in candidates for intensive interventions.

## 1. Introduction

Myelodysplastic syndromes (MDS) are a heterogeneous group of clonal myeloid disorders characterized by peripheral blood cytopenias and increased risk of transformation to acute myelogenous leukemia (AML) [1]. Classical karyotype analyses detect clonal chromosome abnormalities in about 50% of patients with MDS [2]. The karyotype is one of the strongest prognostic parameters in the currently applied prognostic models, including the revised International Prognostic Scoring System (IPSS-R) [3]. In general, the aim is to analyze 20 or more metaphases (MP) before a karyotype is considered to lack specific clonal abnormalities. A lower number of MP analyzed (< 20) is associated with a higher chance of missing small clones [2]. The prognostic relevance of these smaller clones remains to be elucidated in lower-risk MDS [4].

The primary aim of the present study was to assess whether the number of MP examined in patients with normal karyotype provide any additional prognostic information about overall survival (OS) and progression-free survival (PFS) in patients with lower-risk MDS participating in the European MDS Registry Study [5]. The secondary aim was to assess the impact of the number of analyzed metaphases on outcome in patients with an abnormal karyotype. To the best of our knowledge, this is the first prospective study in this field. We hypothesized that a higher number of analyzed nMP does have a positive impact on survival in patients with lower-risk MDS.

## 2. Design and methods

### 2.1. Eligibility

Patients were eligible for inclusion if they were newly diagnosed with MDS according to the WHO 2001 classification [6] and had a low or intermediate-1 risk score according to the IPSS [7]. Patients with post-cytotoxic MDS have been excluded from this Registry. The ethics committees of all participating countries and centers have approved the EUMDS registry (trial number NCT00600860). Patient-specific (including bone marrow morphology, histology and cytogenetics), intervention and outcome data were collected at baseline and at each 6-monthly out-patient follow-up visit for the routine clinical care of

patients with MDS. All subjects were prospectively followed until death, progression to higher-risk MDS or leukemia, loss to follow-up or withdrawal of informed consent.

### 2.2. Assignment of IPSS(-R) score

Both the IPSS cytogenetic score and the IPSS-R cytogenetic score were determined from the diagnostic cytogenetic reports at registration. The local investigator assigned the IPSS cytogenetic scores. The IPSS-R cytogenetic scores were retrospectively assigned by one of the investigators of the EUMDS registry and verified by an independent expert of the international IPSS working group (D. Haase). IPSS and IPSS-R scores were calculated and the IPSS-R cytogenetic risk category of patients with only nMP was assigned as good-risk. In these cases no abnormal MP were reported. Patients with abnormal MP were categorized to the IPSS-R cytogenetic risk score: very good, good, intermediate, poor and very poor risk category [8].

### 2.3. Statistical analysis

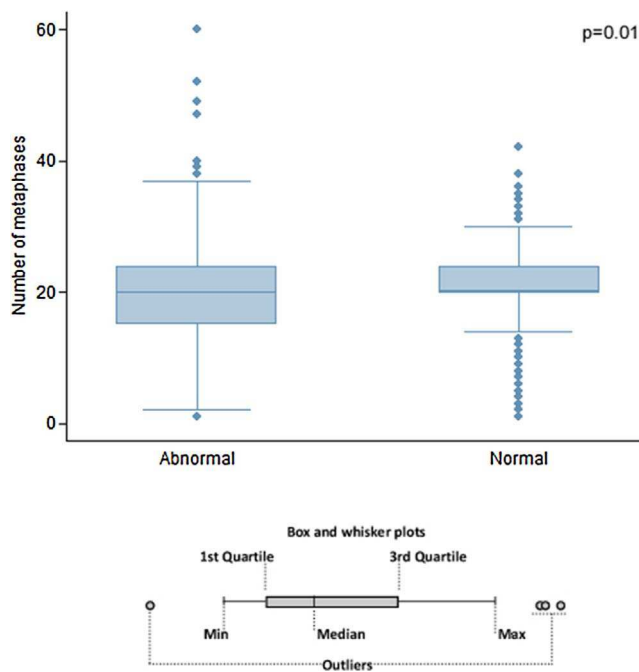
Standard descriptive techniques were used to assess the distribution of baseline patient characteristics including chi squared test and Wilcoxon rank sum test. Overall survival (OS) was defined as the time from date of diagnosis to death, or for subjects still alive at the date of the last follow-up visit. Time to disease progression (TDP) was measured from date of diagnosis to date of disease progression to either higher-risk MDS or acute leukemia. Patients without disease progression were censored at date of death or date of last follow-up visit. Standard methods were used to assess time to event, namely Cox proportional hazards regression models and Kaplan–Meier survival curves. Hazard ratios (HR) and 95% confidence intervals (95% CI) are reported for univariate analyses, unadjusted and adjusted for sex and age at diagnosis. All analyses were undertaken in Stata 14 (StataCorp, College Station, TX).

## 3. Results

In total 2196 patients were registered to the study between 1st April 2008 to 31st March 2017 and patients were followed-up to the 1st June

**Table 1**  
Number of metaphases by age at diagnosis and cytopenias for subjects with a normal karyotype only or an abnormal karyotype.

| Metaphase category (n) | N (%)      | Median age<br>years (range) | Median (25–75 percentile) |                                |   |
|------------------------|------------|-----------------------------|---------------------------|--------------------------------|---|
|                        |            |                             | Hemoglobin (g/dL)         | Platelets (10 <sup>9</sup> /L) | Absolute Neutrophils Count (10 <sup>9</sup> /L) |
| Normal karyotype       |            |                             |                           |                                |   |
| Total                  | 1225 (100) | 73 (18–93)                  | 10.3 (9.2–11.6)           | 171 (96–263)                   | 2.4 (1.3–3.8)                                   |
| 1–9                    | 42 (3.4)   | 72 (47–89)                  | 10.3 (9.2–11.6)           | 179 (88–264)                   | 2.6 (1.2–4.1)                                   |
| 10–19                  | 137 (11.2) | 72 (21–90)                  | 9.8 (8.8–11.4)            | 169 (97–263)                   | 2.4 (1.4–3.7)                                   |
| 20–24                  | 634 (51.8) | 74 (21–93)                  | 10.2 (9.1–11.4)           | 173 (96–270)                   | 2.4 (1.3–3.8)                                   |
| 25–29                  | 164 (13.4) | 73 (42–93)                  | 10.6 (9.7–11.7)           | 160.5 (94–270)                 | 2.2 (1.2–3.6)                                   |
| 30+                    | 72 (5.9)   | 74 (57–90)                  | 10.8 (9.8–12.1)           | 181.5 (99–253)                 | 2.4 (1.4–4.1)                                   |
| Not recorded           | 176 (14.4) | 74 (18–93)                  | 10.6 (9.4–11.8)           | 169 (101–257)                  | 2.4 (1.4–3.9)                                   |
| Abnormal karyotype     |            |                             |                           |                                |   |
| Total                  | 774 (100)  | 75 (21–97)                  | 10 (9–11.1)               | 177.5 (103–283)                | 2.4 (1.4–3.8)                                   |
| 1–9                    | 44 (5.7)   | 70 (39–93)                  | 9.8 (8.9–10.9)            | 162 (67.5–236)                 | 1.8 (1.2–3.3)                                   |
| 10–19                  | 180 (23.3) | 75 (21–93)                  | 10 (9–11.1)               | 197 (114–296)                  | 2.2 (1.4–3.5)                                   |
| 20–24                  | 276 (35.7) | 77 (33–93)                  | 9.9 (9–11.1)              | 168 (103–290)                  | 2.6 (1.5–4)                                     |
| 25–29                  | 104 (13.4) | 74 (34–89)                  | 10.2 (9.1–11.4)           | 181 (106–292)                  | 2.8 (1.5–4.4)                                   |
| 30+                    | 45 (5.8)   | 77 (27–91)                  | 10.3 (9–11.2)             | 189 (98–258)                   | 2.2 (1.4–3.7)                                   |
| Not recorded           | 125 (16.1) | 73 (46–97)                  | 9.7 (8.5–10.9)            | 172 (102–275)                  | 2.1 (1.4–3.6)                                   |



**Fig. 1.** Distribution of number metaphases by abnormal vs normal karyotype. The *p*-value (= .01) shows a significant difference in median number of analyzed metaphases in the normal and abnormal karyotype groups. The aim in assigning an abnormal karyotype is not to analyze 20 or more metaphases (MP) compared to a normal karyotype where the aim is to analyze 20 or more metaphases (MP).

2017. The majority of patients had conventional cytogenetics performed (95%) and 1999 had a karyotype recorded. Sixty-one percent had a normal karyotype (1225/1999) at diagnosis and 39% an abnormal karyotype (774/1999). Patients were subdivided into six categories based on the number of reported MP (Table 1). The median number of MP examined was 20 for patients with normal and abnormal karyotypes, however, the distributions were very different as can be seen in Fig. 1 (*p* = .01). Whilst some patients with an abnormal karyotype had over 40 MP assessed, 35% had less than 20 MP assessed (suboptimal), this is in contrast to those with a normal karyotype where only 17.1% had less than 20 MP assessed (*p* < 0.0001). Patients with an abnormal karyotype were, on average, older (75 vs 73 years, *p* = .03), and in terms of cytopenias they lower hemoglobin values than those with a normal karyotype (*p* < .0001). However, there were no differences in hemoglobin, platelets or neutrophil counts by number of metaphases examined (Table 1).

Table 2 shows the number of normal MP were evenly distributed within the various categories with the exception of the participating countries. The median number of analyzed MP was significantly higher (*p* < .0001) in the two Scandinavian countries compared to the number of MP in Israel, Italy, Serbia, Croatia and Romania. As expected, there were differences between the normal and abnormal karyotypes groups in terms of WHO diagnosis and IPSS-R score; patients with an abnormal karyotype were more likely to have been transfused at diagnosis compared to those with a normal karyotype.

### 3.1. Overall survival and progression-free survival

Median follow-up was 2.1 years (range of 0.1–8.7 years) and 33% (669 of 1999) of patients had died during the observation period; median survival for patients with a normal karyotype was 5.2 years (95% Confidence Intervals (95% CI): 3.3–4.5) and abnormal karyotype (4.0 years (95% CI: 4.0 (4.8–5.9) log rank test = 15.63, *p* = .0001). The univariate overall survival (Fig. 2A and B) and progression-free survival estimates, as depicted in Fig. 3A and B, showed a similar outcome in the six categories throughout the whole observation period.

**Table 2**  
Demographic parameters and impact on median number of metaphases.

| Category                         | Normal karyotype |                           | Abnormal karyotype |                          |
|----------------------------------|------------------|---------------------------|--------------------|--------------------------|
|                                  | No. of patients  | No. of nMP Median (range) | No. of patients    | No. of MP Median (range) |
| Total                            | 1049 (100)       | 20 (1–42)                 | 649 (100)          | 20 (1–60)                |
| Age                              |                  |                           |                    |                          |
| < 60 years                       | 130 (12.4)       | 20 (4–34)                 | 50 (7.7)           | 20 (4–47)                |
| 60–70                            | 247 (23.5)       | 20 (2–42)                 | 138 (21.3)         | 20 (1–52)                |
| 70+                              | 672 (64.1)       | 20 (1–38)                 | 461 (71)           | 20 (1–60)                |
| WHO-diagnosis                    |                  |                           |                    |                          |
| RA                               | 164 (15.6)       | 20 (3–42)                 | 101 (15.6)         | 20 (6–52)                |
| RARS                             | 190 (18.1)       | 20 (1–34)                 | 78 (12)            | 20 (9–34)                |
| RCMD                             | 429 (40.9)       | 20 (2–38)                 | 245 (37.8)         | 20 (1–60)                |
| RCMD-RS                          | 73 (7)           | 20 (3–38)                 | 33 (5.1)           | 21 (7–40)                |
| RAEB-1                           | 143 (13.6)       | 20 (2–35)                 | 60 (9.2)           | 20 (1–47)                |
| RAEB-2                           | 6 (0.6)          | 20 (10–23)                | –                  | –                        |
| MDS-U                            | 44 (4.2)         | 20 (8–34)                 | 29 (4.5)           | 14 (1–30)                |
| 5q-Syndrome                      | –                | –                         | 103 (15.9)         | 20 (3–37)                |
| Country                          |                  |                           |                    |                          |
| Austria                          | 65 (6.2)         | 22 (4–34)                 | 41 (6.3)           | 20 (1–31)                |
| Croatia                          | 2 (0.2)          | 20 (20–20)                | 5 (0.8)            | 16 (7–21)                |
| Czech Republic                   | 50 (4.8)         | 22 (2–25)                 | 42 (6.5)           | 22 (8–40)                |
| Denmark                          | 36 (3.4)         | 25 (10–26)                | 20 (3.1)           | 25 (25–28)               |
| France                           | 291 (27.7)       | 20 (8–36)                 | 162 (25)           | 21 (4–49)                |
| Germany                          | 27 (2.6)         | 22 (2–29)                 | 21 (3.2)           | 22 (5–34)                |
| Greece                           | 70 (6.7)         | 20 (2–29)                 | 58 (8.9)           | 20 (5–52)                |
| Israel                           | 60 (5.7)         | 10 (3–21)                 | 37 (5.7)           | 10 (2–28)                |
| Italy                            | 40 (3.8)         | 17 (1–25)                 | 22 (3.4)           | 14 (3–25)                |
| Netherlands                      | 45 (4.3)         | 20 (10–20)                | 22 (3.4)           | 10.5 (10–30)             |
| Poland                           | 29 (2.8)         | 22 (5–27)                 | 26 (4)             | 21 (18–30)               |
| Portugal                         | 17 (1.6)         | 20 (20–30)                | 16 (2.5)           | 10 (6–29)                |
| Romania                          | 12 (1.1)         | 15 (8–24)                 | 9 (1.4)            | 16 (9–22)                |
| Serbia                           | 8 (0.8)          | 15 (1–15)                 | 8 (1.2)            | 30 (5–30)                |
| Spain                            | 80 (7.6)         | 20 (5–42)                 | 37 (5.7)           | 20 (3–47)                |
| Sweden                           | 54 (5.1)         | 26 (20–38)                | 38 (5.9)           | 25 (20–30)               |
| United Kingdom                   | 163 (15.5)       | 20 (3–30)                 | 85 (13.1)          | 10 (1–60)                |
| IPSS-R <sup>a</sup> Cytogenetics |                  |                           |                    |                          |
| Very Good                        | –                | –                         | 156 (24.0)         | 20 (1–60)                |
| Good                             | 1049 (100)       | 20 (1–42)                 | 250 (38.5)         | 20 (1–39)                |
| Intermediate                     | –                | –                         | 206 (31.7)         | 20 (1–49)                |
| Poor                             | –                | –                         | 21 (3.2)           | 20 (1–60)                |
| Very Poor                        | –                | –                         | 16 (2.5)           | 20 (4–28)                |
| IPSS-R <sup>a</sup> Overall      | 986 (100)        | 20 (1–42)                 | 610 (100)          | 20.0 (1–60)              |
| Very low                         | 309 (31.3)       | 20 (1–42)                 | 166 (27.2)         | 20 (2–39)                |
| Low                              | 480 (48.7)       | 20 (1–38)                 | 245 (40.2)         | 20 (1–60)                |
| Intermediate                     | 161 (16.3)       | 20 (2–35)                 | 152 (24.9)         | 20 (1–40)                |
| High                             | 35 (3.5)         | 20 (10–32)                | 42 (6.9)           | 20 (1–30)                |
| Very high                        | 1 (0.1)          | 20                        | 5 (0.8)            | 20 (5–20)                |
| Transfused at registration       |                  |                           |                    |                          |
| No                               | 761 (72.5)       | 20 (1–35)                 | 427 (65.8)         | 20 (1–60)                |
| Yes                              | 288 (27.5)       | 20 (1–42)                 | 222 (34.2)         | 20 (1–39)                |
| Transfused > 1 unit/month        |                  |                           |                    |                          |
| No                               | 886 (84.5)       | 20 (1–42)                 | 504 (77.7)         | 20.0 (1–60)              |
| Yes                              | 163 (15.5)       | 20 (2–38)                 | 145 (22.3)         | 20.0 (1–39)              |

<sup>a</sup>IPSS-R: Revised International Prognostic Scoring System.

Multivariate analyses were performed to adjust for the various relevant prognostic components: age at diagnosis, MDS WHO category, blast count, hemoglobin levels, platelets and neutrophil count, RBCT-dependency (> 1 unit/month for 6 months) and country. IPSS-R cytogenetic risk category was also included in the model in patients with an abnormal karyotype. The largest category of MP (20–24 MP) was used as the reference category. The number of MP, analyzed both as a continuous variable or as a categorical variable did not significantly influence survival nor progression-free survival. The group with MP not recorded in the database were included in all analyses (Table 3 and Figs. 2 and 3).

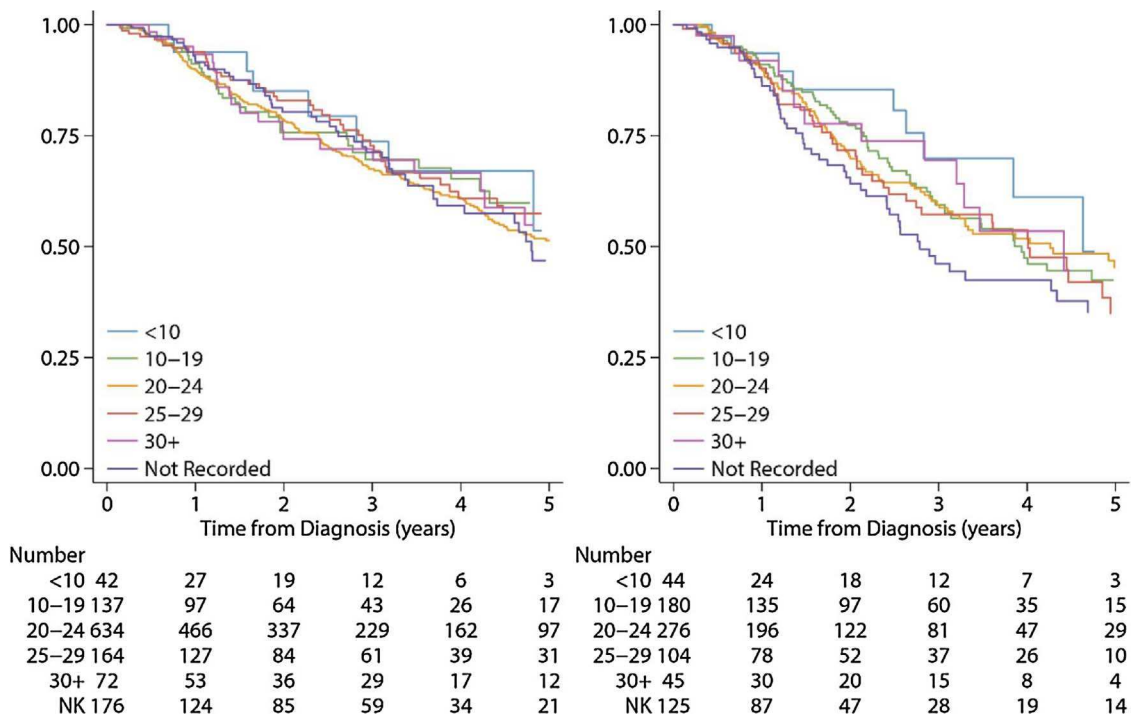


Fig. 2. Overall Survival.

Overall survival from date of diagnosis by the six analyzed categories based on the number of reported metaphases; normal karyotype 2A, and abnormal karyotype 2B. The columns under the figures represent the number of patients in each of the categories at that specific time point.

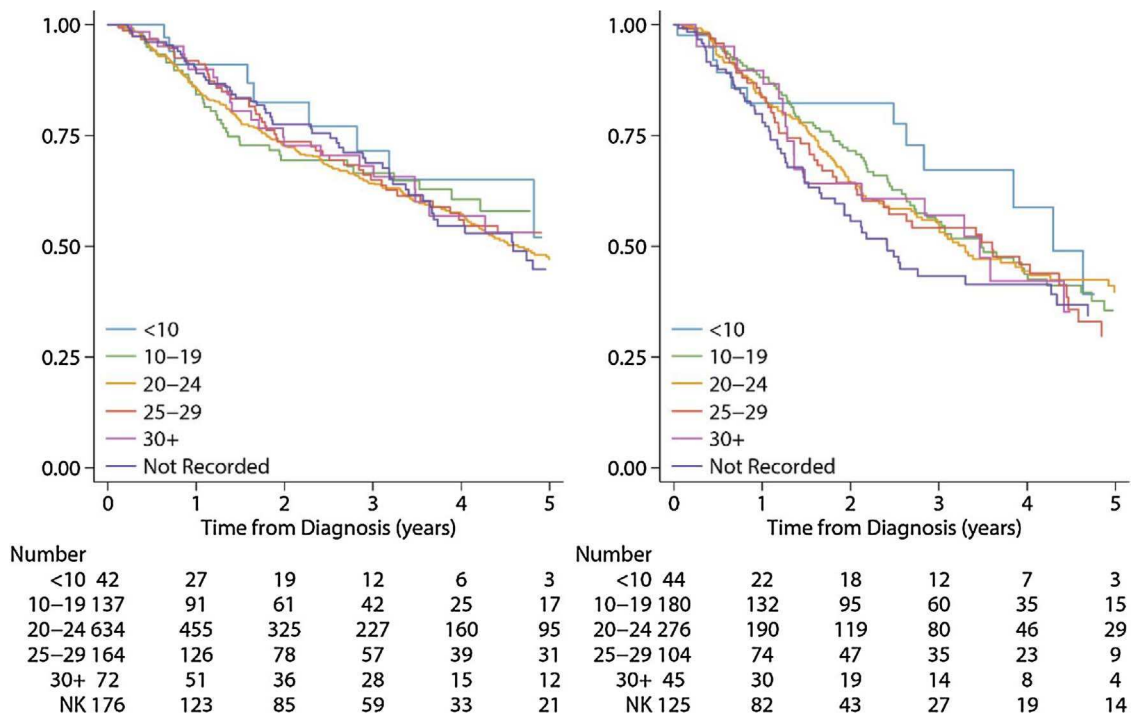


Fig. 3. Progression-free survival.

Progression-free survival from date of diagnosis by the six analyzed categories based on the number of reported metaphases; normal karyotype 2A, and abnormal karyotype 2B. The columns under the figures represent the number of patients in each of the categories at that specific time point.

#### 4. Discussion

The analyses of this study were focused on the impact of analyzable metaphases in patients with a normal karyotype on outcome, including estimated overall survival and progression-free survival. Our recently published study on the first 1000 patients within the EUMDS registry

confirmed established prognostic factors, such as age, gender and World Health Organization 2001 classification [5] in addition, with low health-related quality of life (EQ-5D visual analogue scale score) and a high co-morbidity index predicted poor outcome. The IPSS-R was superior to the original IPSS for predicting both disease progression and survival [5]. We identified 1225 patients with normal conventional

**Table 3**  
Multivariate analyses on impact of number of normal and combined normal/abnormal metaphases on survival and progression-free survival.

| Metaphase category (n) | Normal karyotype |                     |                                   |                           |                                   |
|------------------------|------------------|---------------------|-----------------------------------|---------------------------|-----------------------------------|
|                        |                  | Survival            |                                   | Progression-free survival |                                   |
|                        |                  | HR (95% CI)         | Adjusted HR (95% CI) <sup>a</sup> | HR (95% CI)               | Adjusted HR (95% CI) <sup>a</sup> |
| Continuous             | 1225             | 1.00<br>(0.98–1.02) | 1.00<br>(0.98–1.03)               | 1.00<br>(0.98–1.02)       | 1.01<br>(0.98–1.03)               |
| 1–9                    | 42               | 0.83<br>(0.42–1.61) | 1.06<br>(0.54–2.07)               | 0.77<br>(0.41–1.45)       | 0.98<br>(0.52–1.85)               |
| 10–19                  | 137              | 0.85<br>(0.60–1.22) | 0.94<br>(0.65–1.36)               | 0.88<br>(0.63–1.23)       | 0.96<br>(0.69–1.36)               |
| 20–24                  | 634              | 1 (ref)             | 1 (ref)                           | 1 (ref)                   | 1 (ref)                           |
| 25–29                  | 164              | 0.90<br>(0.66–1.23) | 1.02<br>(0.74–1.39)               | 0.93<br>(0.70–1.24)       | 1.04<br>(0.78–1.39)               |
| 30+                    | 72               | 0.87<br>(0.56–1.36) | 1.05<br>(0.66–1.66)               | 0.84<br>(0.55–1.29)       | 1.00<br>(0.64–1.56)               |
| Not Recorded           | 176              | 1.00<br>(0.74–1.35) | 1.28<br>(0.94–1.75)               | 0.97<br>(0.73–1.29)       | 1.21<br>(0.91–1.62)               |
| Abnormal karyotype     |                  |                     |                                   |                           |                                   |
|                        |                  | HR (95% CI)         | Adjusted HR (95% CI) <sup>b</sup> | HR (95% CI)               | Adjusted HR (95% CI) <sup>b</sup> |
| Continuous             | 774              | 1.00<br>(0.98–1.02) | 0.99<br>(0.98–1.01)               | 1.00<br>(0.98–1.02)       | 1.01<br>(0.98–1.03)               |
| 1–9                    | 44               | 0.83<br>(0.53–1.33) | 0.79<br>(0.41–1.53)               | 0.83<br>(0.47–1.47)       | 0.85<br>(0.47–1.51)               |
| 10–19                  | 180              | 1.01<br>(0.81–1.26) | 1.07<br>(0.77–1.47)               | 0.99<br>(0.74–1.31)       | 1.04<br>(0.78–1.39)               |
| 20–24                  | 276              | 1 (ref)             | 1 (ref)                           | 1 (ref)                   | 1 (ref)                           |
| 25–29                  | 104              | 1.03<br>(0.82–1.29) | 1.21<br>(0.84–1.72)               | 1.09<br>(0.79–1.52)       | 1.15<br>(0.82–1.60)               |
| 30+                    | 45               | 0.91<br>(0.64–1.29) | 0.82<br>(0.47–1.45)               | 1.06<br>(0.65–1.73)       | 0.93<br>(0.57–1.51)               |
| Not Recorded           | 125              | 1.13<br>(0.93–1.37) | 1.27<br>(0.90–1.79)               | 1.31<br>(0.96–1.79)       | 1.20<br>(0.87–1.65)               |

<sup>a</sup> Age, transfused, WHO diagnosis, platelets counts, neutrophil counts, hemoglobin levels, country.

<sup>b</sup> Age, transfused, WHO diagnosis, platelets counts, neutrophil counts, hemoglobin levels, country, karyotype risk category.

karyotype in the EUMDS Registry, representing 61% of this lower-risk MDS patient population. The great majority of patients with normal karyotype had 20 or more MP analyzed, while 14% of the patients were registered with a normal karyotype, based on less than 20 analyzed MP. Estimated overall survival as well as the estimated progression-free survival of the patients with a normal karyotype and a suboptimal number of analyzed MP (< 20) was not inferior when compared with 20 or more analyzed MP. In our study, we found a complete absence of a trend towards an impaired prognostic risk when comparing the varying cohorts. This is not surprising, since the chance of missing a small abnormal clone increases by 25% if only 5 normal MP have been analyzed and between 10 and 15% in patients with 10–15 nMP analyzed [2]. This means that the majority of patients with a suboptimal number of analyzed MP (< 20) are expected to have a conventionally normal karyotype associated with a low risk MDS. In contrast, the size of abnormal clones may play a role in the prognosis [9]. In the study by Mallo et al. the outcome of patients with abnormal clones < 100%, assessed by FISH, was better when compared to patients with 100% abnormal clones [9]. Unfortunately, the impact of smaller clone sizes was not assessed in that study, similar to a large important study, performed by Schanz, et al. [10]. A study of 101 MDS patients with normal karyotype revealed small clones (ranging 15% to 32%) using FISH techniques in 18 patients [4]. FISH abnormalities were predictive for worse prognosis, but the majority of these 18 patients had higher-

risk MDS and all three patients with refractory anemia were surviving at time of evaluation. It is also possible to apply FISH on circulating CD34-positive cells, in order to avoid another BM aspiration to obtain sufficient material for standard banding techniques [11].

Additionally, we analyzed the patients with abnormal karyotypes. As expected the number of analyzed metaphases is lower in this group of patients because the definition of clonality in patients with abnormal karyotype requires a lower number of analyzed metaphases. Also in this group of patients the number of analyzed metaphases does not influence the outcome after adjustment for relevant variables.

Currently, it is possible to detect MDS-specific mutations in more than 90% of patients with MDS [12]. These mutations will allow a better prognostication of all MDS cases with normal karyotype. Therefore, molecular testing should be seriously considered in all fit patients with MDS who are candidates for allogeneic stem cell transplantation or patients in investigational studies, in absence of poor-risk cytogenetic characteristics, as is the case in all patients with MDS, characterized by normal karyotype [13].

In summary: patients with lower-risk MDS with a normal karyotype and suboptimal numbers of analyzable metaphases (< 20) have a similar outcome when compared to patients with optimal numbers of analyzed metaphases (≥ 20). However, it should be a general aim to reach at least a complete analysis of 20 metaphases to be able to exclude clonal cytogenetic abnormalities, especially in patients who are eligible for intensive interventions. If this is not possible, we recommend to use complementary FISH-analyses covering the most frequent cytogenetic changes such as del(5q), monosomy 7/del(7q), trisomy 8, del(17p)/loss of TP53-alleles and del(20q), or additional or molecular techniques [13].

## Acknowledgements

The authors and members of the steering committee of the EUMDS registry would like to thank all local investigators and operational team members for their contribution to the registry, Hassan Mkadmi for his contribution to the initial analyses and Novartis Pharmacy B.V. Oncology Europe for financial support to the EUMDS Registry.

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