Content available at: https://www.ipinnovative.com/open-access-journals

International Journal of Clinical Biochemistry and Research

Journal homepage: https://www.ijcbr.in/

Original Research Article

# Cytogenetic analysis of fanconi anemia patients: An hospital based study

**Ankur Jindal**[1], **Madhavi Puppala**[1], **Sunil Kumar Polipalli**[2,*], **Seema Kapoor**[1]

[1]*Division of Genetics, Dept. of Pediatrics, Maulana Azad Medical College, New Delhi, India*
[2]*Genetic Lab, Dept of Pediatrics, Lok Nayak Hospital, New Delhi, India*

ARTICLE INFO

*Article history:*
Received 04-07-2023
Accepted 12-09-2023
Available online 25-10-2023

*Keywords:*
Chrosomal breakage
Cytogenetic analysis
Fanconi anemia

ABSTRACT

**Background**: Fanconi anemia is a rare genetic disorder caused by mutations in genes whose protein products are involved in replication, cell cycle control and DNA repair and is associated with a very high frequency of bone marrow failure and many other manifestations including, but not restricted to, severe birth defects.
The diagnosis of FA is confirmed by a specific test known as chromosomal breakage study, a differential technique in which clastogenic substances, such as DEB (diepoxy butane) or MMC (mitomycin C), lead to sections of the chromosome being deleted, added, or rearranged.
In this retrospective study, peripheral blood smears of patients with Aplastic Anemia were analyzed to diagnose Fanconi Anemia.
**Materials and Methods**: A total of 135 cases of Aplastic anemia were analyzed and screened by chromosomal breakage analysis for ruling in/out Fanconi anemia.
**Results**: A total of 9 (6.66%) out of 135 patients showed a significant increase in the number of chromosomal breaks in comparison to their control. An analysis of the variable clinical manifestations was also done and correlated to the diagnosis of Fanconi Anemia.
**Conclusion**: This study throws light on the importance of cytogenetic analysis as being the most classical test for FA which involves detection of chromosomal breakage or aberrations in metaphase spreads. This relatively inexpensive assay may be useful for screening patients for whom FA is in the differential diagnosis, such as those with radial ray anomalies, short stature, hypogonadism, or café au lait spots, or for population-based FA incidence studies.



## 1. Introduction

Fanconi anemia (FA; OMIM 227650) is an autosomal recessive condition that can cause serious birth abnormalities in addition to high incidence (1 in 360,000) in infants with bone marrow failure and other symptoms. Swiss pediatrician Guido Fanconi originally described this condition in the year 1927. Fanconi Anemia is a rare and diverse genetic condition that affects all racial and cultural groups.

If this hematologic disease condition diagnosed in early stage it enables effective management before development of thrombocytopenia, and elective surgery with appropriate family genetic counseling for identification of presymptomatic siblings with FA, identification of unaffected siblings or pregnancies which might serve as donors for hematopoietic stem/progenitor cells for an FA patient with bone marrow disease, and targeted cancer surveillance. FA patients may also present with Acute myeloid leukemia (AML), aplastic anemia (AA), myelodysplastic syndrome (MDS), solitary cytopenias without any other cause (such as antibodies), or macrocytic

* *Corresponding author*.
*E-mail address*: sunilpkumar18@gmail.com (S. K. Polipalli).

https://doi.org/10.18231/j.ijcbr.2023.036

red cells without any other explanation (such as vitamin B12 or folate deficiencies).

FA should be considered in patients who are children or young adults with unexplained cytopenias, particularly if a stem cell transplant is planned and have either diagnosis (MDS and AML). The relative risk of AML is 800-folds, and the median age in reported cases is 14 years, with a range from <1 to 30 years of age. The frequency of MDS is unknown, and the temporal relation between MDS and AML is not clear.[1,2]

Most common cause of FA is bone marrow failure, which inherit from one generation to next generation in X linked autosomal recessive manner as many genes are involved for this condition which present on X chromosome. However all these genes work in the same manner, product of these genes interfere in DNA repair mechanism.[3–5] Patients are at extended chance for hematological and strong tumors (inclusive of leukemia, carcinomas, and liver tumors).[3,4] Given the importance of identifying these patients as there is a paucity of data in Indian scenario, we mainly focused on their clinical characteristics and with the objective to analyze the findings of chromosomal breakage test (CBT) using mitomycin-C (MMC) for the screening of aplastic anemia (AA) for Fanconi Anemia.

## 2. Material and Methods

### *2.1. Study subjects*

This was the retrospective study in which a total of 135 patients were enrolled. Peripheral blood sample were collected from all the cases of AA for chromosomal breakage study for ruling in/out Fanconi anemia. The patients age ranged between 6 months to 18 years, and the female: male ratio was 0.84: 1. This study was approved by the Institutional Ethics committee of MAMC, New Delhi. Chromosomal Breakage Test(CBT) for the diagnosis of FA is performed in Patients and Controls at Pediatrics Research and Genetic lab, Department of Pediatrics, Maulana Azad Medical College (MAMC) & Associated Lok Nayak Hospital, New Delhi. This CBT is a diagnostic test to rule out FA. This test was done on request of clinician for the patients having symptoms of Aplastic anemia, clinical features of FA, sibling of already diagnosed FA, patient with bone marrow failure, AML and MDS.

### *2.2. Lymphocyte culture for chromosome breakages*

For this test About 1 ml of peripheral blood was collected in heparin sterile vial from each patient and age and sex 'matched' healthy control. A recent CBC (complete blood count) report was provided; because a minimum WBC count of 2000/ml is required for a successful culture. Two different cultures were set up for each specimen. A 72-hour PHA stimulated culture for routine study (Culture A), a second 72-hour PHA stimulated culture with applying 0.4 ml of Mitomycin C (MMC) (0.1 mg/100 ccd H2O) from the same specimen (Culture B). Each culture was harvested in appropriate time and 10-15 microscopic slides were prepared for each specimen. GTG banding technique was used for routine analysis and 1- 2 slides of the Mitomycin C treated culture for any possible chromosomal rearrangements such as radials, exchanges, and endoreduplications. The rest of slides were stained with Giemsa stain (solid stain technique) for detecting any chromosomal breakages such as chromosomes breaks, chromatid breaks, gaps and radials. 100 metaphases were studied (25 metaphases from routine culture, 25 spreads from culture prepared with addition of mitomycin C and 25 spreads from age related normal controls). The breaks were calculated and reported as average per metaphase and were compared with normal controls. From cytogenetic point of view, breakage less than 10 fold of control is not clinically significant.

For each individual, after culturing and harvesting G banding followed by trypsin were performed according to the procedure described by Seabright (1971). The technique for chromosomal breakage study by using Mytomycin-C was first described by Auerbach etal. In 1981 in which Lymphocytes culture were implanted with phytoheamagglutinin for both the control and patient samples. After this results were analyses for both the control and patient samples. Metaphase was analyzed under the microscope, mean chromosome breakage and radial formation was identified. Cytogenetic analysis was done in all the patients and results were analysed using GTG banding, with the minor modification of technique described by Yunis.[6] The results were all reviewed using the International System for Cytogenetic Nomenclature (ISCN) published in 2020.[7]

## 3. Results

In the present study, 135 cases of Aplastic anemia were screened by chromosomal breakage analysis out of which 96 (71%) were males and 39 (28.8%) females. Only 9 patients (6.66%) out of 135 cases showed multiple breakage and radial formation and 126 patients (93%) showed normal karyotype. Chromosomal fragility test showed positivity in 6.66% of cases with the patients those were clinically suspected for fanconi anemia.

The clinical characteristics of these cases were tabulated (Table 1). Our findings presented with short stature (83%), developmental delay (45.92%) and delayed speech (29.62%). Hematologic changes were thrombocytopenia (57.77%), pancytopenia (56.29%), anemia (80.74%) present in both the groups. Phenotype in the patients with FA was microcephaly (8.88%), triangular face (11.11%), café au lait spots (2.96%) and hyperpigmentation of neck (5.18%). 2 cases (1.48%) also showed inguinal hernia. Radial changes were found with single palmer crease (3.70%), clinodactyly

of fifth finger (1.48%), radial anomalies (5.18%) and radial hypoplasia (7.40%). Other changes were lymphedema (5.18%), congenital heart disease (5.18%), renal anomaly (2.96%), vertebral deformities (6.66%). 0.074% of the cases did not show any dysmorphism.

For Cytogenetic analysis of chromosomal fragility, mitomycin C were induced to test the study group. Further they were divided into two subgroups: one group showing the typical mitomycin cellular response (multiple breakage and radial formation) fanconi and the other group non-Fanconi. 30 metaphases were analyzed. Chromatid, chromosome breaks, acentric fragments, dicentric and radial figure were scored. Spontaneous, mitomycin induced breaks for both groups are presented in Table 2.

The mean chromosomal breakage frequency in peripheral blood lymphocyte for normal control individual range from 0.00- 0.05 with a mean 0.05 breaks /cell. The results of the 135 AA patients with CBT were as follows: Eighty-six patients (63.7%) had 0-2% of cells with chromosome breakages, 27 patients (20.0%) had 3-10% aberrant cells, 9 patients (6.6%) had 11-20% aberrant cells, 4 patients (~3%) had 21-30% and 9 patients (6.6%) had more than 30% aberrant cells. When more than 30% of cells examined show chromosome aberrations (breakages and/or radial formation) the results were considered positive for CBT. Nine out of 135 AA patients were positive for CBT. The Mytomycin-C induced metaphase spread of an AA patient with chromosome aberrations (multiple chromosome breakages and the presence of a radial) were positive for CBT. Only 0-2% of cells showed aberrant cells in normal 82 controls, in which 97.5% of them do not show any chromosomal breakage. Only single break was observed in the aberrant cells. In relation to the mean of mitomycin – C induced chromosomal breakage frequency were (0.75-2.50 with a mean 1.38 breaks /cell).

## 4. Discussion and Conclusions

The astute clinician Guido Fanconi was first discovered this condition and known as Fanconi Anemia.[8] He could not imagine that this disease would eventually reveal an important mechanism of cellular defense against genetic instability.[9]

FA is an inherited bone marrow failure syndrome, a rare disorder resulting from autosomal or rarely X-linked recessive inheritance associated with congenital abnormalities, hypersensitivity to DNA cross-linking agents that are characterized by chromosomal fragility and increased cellular hypersensitivity to specific mutagenic agents and radiation.[10,11] However all these genes have one thing in common that they do not allow the deoxyribonucleic acid (DNA) repair mechanism work properly.[12] The diagnosis of FA is usually confirmed by a specific test known as chromosomal breakage study, a differential technique with clastogenic substances, such as mitomycin C (MMC), used to promote DNA damage, breakage and rearrangement of chromosomes and cell death.

This is very important because although people with the syndrome have a spontaneous tendency to break chromosomes, in some cases primary cultures (without these agents) can give normal results (which are considered false negatives). These include ataxia-telangiectasia (AT), Nijmegen rupture syndrome (NBS), Bloom syndrome (BS), xeroderma pigmentosum (XP), Cockayne syndrome (CS), Werner syndrome (WS), trichothiodystrophy syndrome (TTD), Rothmund-Thompson syndrome (RTS), and ICF, centrochromic trait syndrome, centrochromic trait and spontaneous (centrochromic trait syndrome). drome). so FAs cannot be distinguished by this feature.[13]

The clinical variability of FA makes its clinical diagnosis difficult.[14] This phenomenon could be observed in the subjects, whose phenotype varied from isolated pancytopenia to patients with multiple malformations and no hematological disorders.

However, there are some clinical features that can help make a diagnosis of FA. For example, findings seen only in FA patients included some craniofacial abnormalities (such as a triangular face and protruding ears) and Café au lait spots. Craniofacial abnormalities have been described in the literature in 25% of FA cases. Other abnormalities include epicanthal folds, strabismus, hypertelorism, ear canal stenosis, and microtia. These findings were also evident in our patients.[2,14] Although craniofacial abnormalities are subtle, some authors suggest that they may allow clinical identification of patients with FA.[15] Skin abnormalities, on the other hand, are described in the literature in 45-60% of cases.

In our study, Café au lait spots and local or generalized hyperpigmentation (2.96%) (5.18%) were present. Radial abnormalities, a classic FA finding, were reported in approximately (5.18%) children and mostly (7.40%) include absence or hypoplasia of the thumb, double or extra thumbs, and absence or hypoplasia of radial abnormalities in (5.18%) patients. Radial deviations can be unilateral or bilateral, and even individuals with bilateral deviations usually have some asymmetry and have different limb deviations, these findings confirmed with previous studies.[2,12,14,15]

In our study Radial abnormalities and hematological dysfunction were common in both groups (with and without FA), and this finding may be related to the fact that these are the main reasons for suspecting FA.[6,16–18] Conversely, neurological disorders such as hypotonia, neuropsychomotor development delay, speech delay are found in individuals without this diagnosis. In this study (45. 92%) developmental delay and (29.62%) speech delay was observed.

**Table 1:** Cases with clinical findings in the Aplastic Anemia patients, grouped according to whether there was or not diagnosis of Fanconi anemia

| Findings | Fanconi Anemia | | Total n=135 |
|---|---|---|---|
| | Yes n=9 | No n=126 | |
| Short stature | 5 | 108 | 113 (83.7%) |
| **Neurological** | | | |
| Developmental delay | 4 | 58 | 62 (45.92%) |
| Delayed speech | 4 | 36 | 40 (29.62%) |
| **Craniofacial** | | | |
| Microcephaly | 6 | 6 | 12 (8.88%) |
| Triangular face | 5 | 10 | 15 (11.11%) |
| Epicanthic fold | | | |
| Hypertelorism | | | |
| Micrognathia | | | |
| Prominent ears | | | |
| **Skin** | | | |
| Café au lait spots | 3 | 1 | 4 (2.96%) |
| Hyperpigmentation of the neck | 6 | 1 | 7 (5.18%) |
| **Abdomen** | | | |
| Inguinal hernia | 2 | | 2 (1.48%) |
| **Upper Limbs** | | | |
| Single palmar crease | 4 | 1 | 5 (3.70%) |
| Clinodactyly of fifth finger | 2 | | 2 (1.48%) |
| Radial anomalies | 1 | 6 | 7 (5.18%) |
| Radial hypoplasia | 4 | 6 | 10 (7.40%) |
| Dysplastic nails | | | |
| **Lower limbs** | | | |
| Lymphedema | 1 | 6 | 7 (5.18%) |
| Congenital heart disease | 1 | 6 | 7 (5.18%) |
| Renal anomaly | 4 | | 4 (2.96%) |
| Vertebral deformities | 1 | 8 | 9 (6.66%) |
| **Hematologic** | | | |
| Thrombocytopenia | 6 | 72 | 78 (57.77%) |
| Pancytopenia | 8 | 68 | 76 (56.29%) |
| Anemia | 9 | 100 | 109 (80.74%) |
| Without Dysmorphism | 1 | | 1 (0.74%) |

**Table 2:** Results of Mytomycin-C induced chromosomal breakage test to diagnose Fanconi anemia in Aplastic anemia patients

| Aberrant Cells (%) | No. of Breaks in cell (if present) | Fanconi Anemia | |
|---|---|---|---|
| | | Yes n=9 | No N=126 |
| 0-2% | 5 | - | 86 (63.7%) |
| 3-10% | | - | 27 (20%) |
| 11-20% | | - | 9 (6.6%) |
| 21-30% | | - | 4 (~ 3%) |
| Above 30% | | 9 (6.6%) | - |

* :number varies from single to multiple breaks without/ with radial forms.

Another important aspect of FA is the short lifespan of this disease (on average 20 years) and the probability of survival beyond 50 years is almost zero.[16,18] This is mainly due to aplastic anemia and the increased likelihood that these patients will develop acute myeloid leukemia, myelodysplastic syndrome, or solid tumors (especially after 20 years).[2,18]

Advances in the treatment of hematological disorders in FA patients, infections have become the most important clinical complication even after the development of new antibiotics.[15] Many children with FA eventually die from bacterial and fungal infections, and neutropenic infections are generally poorly tolerated and usually do not resolve with antibiotics alone,[15] as was the case in one patient in our sample. Changes in growth parameters such as height, weight and/or head circumference also tend to fall below the fifth percentile in FA patients.[14] Our sample included patients with short stature (n = 1) and microcephaly (n = 2).

Other less common abnormalities, such as cardiac and renal disease,[2] were not observed in FA patients in our study.

A parental relative was found in only one patient with FA and is related to the etiology of the syndrome, because, as previously mentioned, most cases segregate in an autosomal recessive form. Regarding family history, four FA patients had relatives with spectral abnormalities of the syndrome, and these abnormalities were observed in only one person in the other group. The significance of this finding could not be determined; However, this may indicate that there are several affected individuals in the same family. However, further clinical data and additional diagnostic tests would be needed to confirm this hypothesis.

In this study, the chromosomal fragility test was performed with MMC, a total of 9 (6.66%) out of 135 patients showed a significant increase in the number of breaks compared to the control group. Our results are compared with those of a normal control group, especially for gender and age. At least 30 metaphases per culture are analyzed microscopically. Chromosomes in FA patients tend to spontaneously rupture and break more easily in the presence of DNA cross-linking agents. The degree of sensitivity to MMC did not correlate with disease phenotype or severity. In addition, it is important to be aware that individuals heterozygous for FA cannot be detected by this MMC test.[2,5,7,19,20] Another interesting aspect was related to the points where the chromosome breaks. Some studies, such as Schoder and others,[21] have shown that these sites have a significant association with fragile sites, which are chromosomal regions that can have many gaps and breaks in metaphase chromosomes in healthy individuals.

The International Fanconi Anemia Registry (IFAR) study showed that the range of spontaneous chromosome breaks (0.02-1.90 breaks per cell with a mean of 0.27) in the FA group of 104 patients overlapped that of the non-FA group of 224 patients. patients (0.00-0.12 break/mean 22). This study confirmed the unreliability of baseline chromosomal breakage in the differential diagnosis of FA.[22,23] Thus, baseline rupture frequency has not been shown to be a useful method for differentiating patients with FA.

According to the MMC sensitivity test, the percentage of MMC-induced aberrant cells increased in FA patients than in non-FA patients in the studied groups. There was a clear distinction between FA and other FA subgroups, with no overlap. The IFAR study also significantly differed between the FA group and the non-FA group based on MMC-induced chromosomal fragility. The percentage of induced aberrant cells in their study was 85.15% in FA patients and 5.12% in the non-FA group.[22] Our results are consistent with the IFAR report[22] and other similar studies[21,23] in that FA and non-FA groups can be distinguished based on the percentage of MMC-induced aberrant cells. In addition, FA not only affects the somatic compartment, such as chromosomal instability and cell death, but also affects germ cells and induces infertility in FA patients.[24]

Currently, there is consensus in the literature that due to FA phenotypic concordance between affected siblings, all siblings of a patient with FA should be screened for the syndrome.[14] Tests for Fanconi anemia vary. Cytogenetic analysis is the most classic and available FA test, which includes the detection of chromosome breaks or metaphase spread abnormalities. It is widely used in the chromosome breakage test.[25] This test gives an accurate result in patients with MDS or AML. This relatively inexpensive assay may be useful in the differential diagnosis of patients with FA, such as those with radial abnormalities, short stature, hypogonadism or Café au lait spots, or in population-based FA prevalence studies.[13] Appropriate medical management, targeted genetic counseling, premarital screening, prenatal diagnosis, and preimplantation diagnosis can be performed. Potential bone marrow transplant donors, such as phenotypically and hematologically "normal" siblings, can be accurately genotyped to avoid the use of undiagnosed homozygotes as donors.

## 5. Source of Funding

This work was supported by a grant from the Council of Scientific and Industrial Research with 27(0275)/12/EMR-II.

## 6. Conflict of Interest

None.

## References

1. ZenI PRG, Moraes FN, Rosa RFM, Graziadio C, Paskulin GA. Clinical characteristics of patients with fanconi anemia. *Rev Paul Pediatr*. 2011;29(3):392–9.
2. Sagaseta IM, Molina J, Lezáun I, Valiente A, Durán G. Anemia de Fanconi. Consideraciones actuales. *Anales Sis San Navarra*. 2003;26:63–78.
3. Kennedy RD, D'Andrea AD. DNA repair pathways in clinical practice: lessons from pediatric cancer susceptibility syndromes. *J Clin Oncol*. 2006;24(23):3799–808.
4. Tootian S, Mahjoubi F, Rahnama M, Hormozian F, Mortezapour F, Razazian F. Cytogenetic investigation in Iranian patients suspected with Fanconi anemia. *J Pediatr Hematol Oncol*. 2006;28(12):834–6.
5. Taniguchi T. Fanconi Anemia. In: Pagon RA, Bird TC, Dolan CR, Stephens K, editors. Gene Reviews. Seattle (WA): University of Washington; 1993.
6. Magdalena N, Pilonetto DV, Bitencourt MA, Pereira NF, Ribeiro RC, Jeng M, et al. Frequency of Fanconi anemia in Brazil and efficacy of screening for the FANCA 3788-3790del mutation. *Braz J Med Biol Res*. 2005;38:669–73.
7. Lima CS, Lourenço GJ, Rodriguez DE, Zocca M, Bertuzzo CS. Cytogenetic and molecular diagnosis of Fanconi anemia. *Rev Bras Hematol Hemoter*. 2003;25:191–2.
8. Lobitz S, Velleuer E. Guido Fanconi (1892-1979): a jack of all trades. *Nat Rev Cancer*. 2006;6(11):893–8.
9. Winter JPD, Joenje H. The genetic and molecular basis of Fanconi anemia. *Mutat Res*. 2009;668(1-2):11–9.
10. Auerbach AD, Wolman SR. Susceptibility of Fanconi's anaemia fibroblasts to chromosome damage by carcinogens. *Nature*. 1976;261(5560):494–6.

11. Tischkowitz MD, Hodgson SV. Fanconi anaemia. *J Med Genet*. 2003;40(1):1–10.
12. Chowdhry M, Makroo RN, Srivastava P, Kumar M, Sharma S, Bhadauria P. Clinicohematological correlation and chromosomal breakage analysis in suspected Fanconi anemia patients of India. *Indian J Med Paediatr Oncol*. 2014;35(1):21–5.
13. Ćirković S, Guć-Šćekić M, Vujić D, Mićić D. Cytogenetic diepoxybutane sensitivity in serbian children with fanconi anemia. *Arch Biol Sci Belgrade*. 2006;58(4):215–9.
14. Auerbach AD, Adler B, Chaganti RS. Prenatal and postnatal diagnosis and carrier detection of Fanconi anemia by a cytogenetic method. *Pediatrics*. 1981;67(1):128–35.
15. Green AM, Kupfer GM. Fanconi anemia. *Hematol Oncol Clin North Am*. 2009;23(2):193–214.
16. Joenje H, Patel KJ. The emerging genetic and molecular basis of Fanconi anaemia. *Nat Rev Genet*. 2001;2(6):446–57.
17. Chen H. Atlas of genetic diagnosis and counseling. New Jersey: Humana Press; 2006.
18. Jones K. Smith's recognizable patterns of human malformation. 6th ed. Philadelphia: Elsevier; 2006.
19. Brown MG, Lawce HJ. Peripheral blood cytogenetic methods. In: The AGT cytogenetics laboratory manual. Philadelphia: Lippincott-Raven; 1997. p. 163–7.
20. Korgaonkar S, Ghosh K, Vundinti BR. Clinical, genetic and cytogenetic study of Fanconi anemia in an Indian population. *Hematology*. 2010;15(1):58–62.
21. Ilgin H, Akarsu AN, Bokesoy FI. Cytogenetic and phenotypic findings in Turkish patients with Fanconi anemia. *Tr J Med Sci*. 1999;29(2):151–4.
22. Auerbach AD, Rogatko A, Schroeder-Kurth TM. International Fanconi Anemia Registry: relation of clinical symptoms to diepoxybutane sensitivity. *Blood*. 1989;73(2):391–6.
23. Kook H, Cho D, Cho SH, Hong WP, Kim CJ, Park JY, et al. Fanconi anemia screening by diepoxybutane and mitomycin C tests in Korean children with bone marrow failure syndromes. *J Korean Med Sci*. 1998;13(6):623–8.
24. García-De-Teresa B, Rodríguez A, Frias S. Chromosome Instability in Fanconi Anemia: From Breaks to Phenotypic Consequences. *Genes (Basel)*. 2020;11(12):1528.
25. Zhang XX. Chromosome instability. In: The principles of clinical cytogenetics. New Jersey: Humana Press; 2005. p. 350–1.

## Author biography

**Ankur Jindal,** Research Associate https://orcid.org/0000-0002-0955-3248

**Madhavi Puppala,** Research Associate

**Sunil Kumar Polipalli,** Cytogeneticist https://orcid.org/0000-0003-4816-2474

**Seema Kapoor,** Director Professor

**Cite this article:** Jindal A, Puppala M, Polipalli SK, Kapoor S. Cytogenetic analysis of fanconi anemia patients: An hospital based study. *Int J Clin Biochem Res* 2023;10(3):204-209.